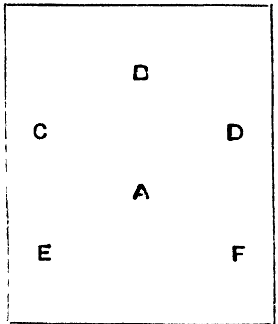
A PRACTICAL TREATISE

ON

OUTBREAKS OF FIRE.

KEY TO, AND DESCRIPTION OF, FRONTISPIECE.



A. The Egyptian lioness-headed Fire-goddess Sekhet (B.C. 1450) who symbolised the fierce destructive heat of the sun. She wears the solar disc and uræus, and holds in her right hand the symbol of life and in her left the papyrus sceptre.

This illustration is from a photograph of the statue in the Temple of Ptah and Hathor, one of the temples at Karnak Thebes. The chamber in which the statue is situated is almost entirely dark; but one ray of light is admitted through a small hole in the roof. This beam impinges upon the upper part of the head and produces such a sinister effect that the native guides will not enter the chamber.* It was taken in 1915 by the author's nephew, Captain Eric Archard Jones, 7th Middlesex Regt.

B. JAN VAN DER HAIJDEN, Engineer, introducer of leather hose and maker of Fire Pumps. General Fire Chief of Amsterdam. Born 1637 at Gorinchen, died 28th March, 1712.

C. JAMES BRAIDWOOD, Surveyor, Associate of the Institution of Civil Engineers. Superintendent of the Edinburgh Fire Engines, 1823-33; London Fire Engine Establishment, 1833 to the time of his death. Born at Edinburgh, 1800. Killed at the great Tooley Street Fire, 22nd June, 1861; author of the first book in English on Fire Prevention and Fire Extinction, etc. (1830).

D. SIR EYRE MASSEY SHAW, K.C.B., Subaltern, North Cork Rifles; Chief of the Belfast Fire Brigade, 1860. Superintendent, London Fire Engine Establishment, 1861-66. Chief Officer, Metropolitan Fire Brigade, 1866 to 1st November, 1891. Born at Ballymore, 1830. Died 25th August, 1908. Author of "Fire Protection," "Fire Surveys," "Fires in Theatres," etc.

E. THOMAS GREEN, Ironmonger, Alderman of the City and County of Oxford, Chief Officer of the Oxford Fire Brigade, Founder of the National Fire Brigades' Union. Born at Brighton, 1828. Died at Oxford, 24th December, 1897. Author of "Fires in and about Oxford," etc.

F. EDWIN OCHS SACHS, Architect, Founder and Chairman of the British Fire Prevention Committee. Untiring in his activity in relation to all questions regarding fire protection. After leaving University College, London, he studied construction and fire protection for some years in the principal European cities. Born in London, 1870. Died 9th September, 1919. Author of "Modern Opera Houses and Theatres," "What is Fire Protection?" etc.

The background of smoke is from a photograph of a number of railway trucks containing petroleum on fire by the side of the Manchester Ship Canal.

* One can, therefore, well imagine that in ancient times when the Goddess was believed to have been the blood-thirsty agent of the Sun-god in the great massacre of mankind, this sanctuary must truly have been a place of terror. (From A. E. P. Weigall's "Guide to Antiquities of Ancient Egypt.")

A PRACTICAL TREATISE

ON

OUTBREAKS OF FIRE

BEING A SYSTEMATIC STUDY OF THEIR CAUSES AND MEANS OF PREVENTION

Dealing with the Possibilities of Danger, Precautions Necessary, Notification, Extinction, Equipment for Saving Life and Property, Organisation of Fire Brigades both Private and Public, Notes on Structural Design of Buildings, Legal Enactments and Fire Insurance, Historic Conflagrations and their Lessons.

BY

SIDNEY GOMPERTZ GAMBLE, F.S.I., A.M.I.C.E., M.I.Fire E.

For twenty-six years Second in Command of the London Fire Brigade; Hon. Life Member of the National Fire Brigades' Association; Vice-President South Midland District, National Fire Brigades' Association; Membre d'honneur, Fédération des Officiers et Sous Officiers de Sapeurs-Pompiers de France et d'Alger; Russian Imperial Fire Service Council, 1913; Member of the International Fire Service Council; Member of the Council of the Institution of Fire Engineers.

With Frontispiece, Plates and 348 Illustrations in the Text, Tables, List of Great Fires, with Dates.

THIRD EDITION

SECOND IMPRESSION.

LONDON:

CHARLES GRIFFIN AND COMPANY, LIMITED,

42 DRURY LANE, W.C. 2.

1942

Printed in Great Britain by
Bell and Bain, Limited, Glasgow.

FOREWORD.

THE pleasant privilege of writing a Foreword to Mr. Gamble's book has fallen to my lot as President, for the time being, of the National Fire Brigades' Association. I am in the position of one who is fortunate enough to be the bearer of a welcome message or who has to announce an arrival that has been long expected and hoped for.

This book has been written to meet a definite need and also in fulfilment of the strong wish of many persons who are concerned with the protection of the community against the constant and insidious danger of fire. The prevention and extinction of outbreaks of fire has become a highly technical and complicated business, and the Fireman of to-day requires, not only an intensive physical training, but also a great deal of scientific instruction. He has to face dangers and difficulties which were not even dreamed of fifty years ago on account of the great changes which have taken place in architecture and the presence even in ordinary dwelling-houses of explosive and inordinately inflammable substances, of electric currents and of obstacles that can only be removed by a skilled engineer.

The Fireman, just as much as the sailor and soldier, has to be trained for "chemical warfare," and his business is, not only to save property, but even more to save life. For the latter purpose he has to be carefully instructed in First Aid and Ambulance work, besides being taught the use of a great deal of complicated apparatus for fire-fighting.

The Fireman's vocation has, therefore, become in an ever-increasing degree an art and a science, and those who have undertaken the public-spirited and responsible task of training and controlling Fire Brigades have felt the pressing need for a compendious handbook of the knowledge which they are expected to possess.

Mr. Gamble has now performed the formidable task of providing such a handbook, and it is fortunate that such long and wide

experience as his should have been made available for all concerned by literary powers and studious industry which are rarely possessed by those who have the practical experience. Into this book Mr. Gamble has compressed everything of practical value that he has learnt during fifty years of fire-fighting and in the course of his profession as an Architect and Borough Surveyor. We have, therefore, not merely the one-sided view of an enthusiast in Firemanship, but rather the broad outlook of a man who has been obliged to survey the question from the civic, economic, and national standpoint, and the work is a fitting crown to a life of public-spirited activity and "national service" in the truest sense of that term.

I cannot doubt that this book will go far to encourage the zeal which already exists to such a high degree among Firemen. It will stimulate further scientific study of Firemanship in all its branches, and take its place immediately as the standard book of reference on its subject.

It is most gratifying to me to be the first to offer congratulations to Mr. Gamble, and to express the hope that this treatise will make his name honoured far and wide for years to come.

I desire also to congratulate the Publishers, whose enterprise and skilful collaboration with the author adds yet further to their great reputation as technical publishers.

AMPTHILL,

President,

National Fire Brigades' Association.

OAKLEY HOUSE,

BEDFORD, *31st December*, 1925.

PREFACE.

THIS treatise is the outcome of half a century of practical experience in dealing with outbreaks of fire and their extinction, as well as of a constant examination into the causes of fires and consideration of the means of their prevention.

During recent years a number of publications, large and small, on special aspects of this subject, such as Chemistry in relation to Fires, Fire Danger in Coal Mines, etc., have appeared, but the need for a comprehensive work remains, and to supply this the present treatise has been prepared.

The subject is one of international importance, and presents a great variety of problems of which few people have cognisance. The writer's official position for twenty-six years as Second Officer in The London Fire Brigade, and prior to that for over seventeen years as Borough Surveyor and Chief Officer of the Fire Brigade of a provincial town, has given him abundant opportunity for studying these problems from the fireman's point of view. The complexity of the subject has increased with the growth and greater diversity of manufactures, which have necessitated a corresponding advance in knowledge by those engaged in the hazardous task of fire fighting, whilst brigade work has become more exacting, calling for a deeper acquaintance with the application of general science.

The Author has endeavoured to present a complete study of the whole subject in concise and homely language, with the hope that firemen everywhere may profit by reading it, and that it may be of service to fellow-officers in Fire Brigades, Municipal Councillors, Factory and other Government Inspectors, Surveyors and Architects, Engineers, Dock, Harbour, and Railway Officials, Ships' Officers, Police and many large business concerns having volunteer fire brigades, as well as property owners, who would be well advised personally to consider so important a subject. Officials connected with Fire Insurance Companies are so intimately concerned that to them the book will speak for itself.

The Author tenders grateful thanks to Lord Ampthill for his kindly Foreword, as well as to many other friends for assistance in the preparation of his manuscript, and in particular desires to thank Major J. G. Blow, M.C., R.E., Capt. A. V. Sutherland Graeme, A.R.I.B.A., D. W. Wood, Esq., M.B.E., A.M.I.Fire E., and also the Executive of the British Fire Prevention Committee for placing at his disposal the information contained in their "Red Books," as well as for their permission to reproduce certain illustrations from their Journals. It is also due to his publishers to acknowledge their guidance and help in making ready the work for press and for so fully illustrating it.

S. G. G.

LONDON,
January, 1926.

PUBLISHER'S NOTE TO THIRD EDITION.

THAT this work is proving of service in the National Emergency is evidenced by the insistent call for more copies. The question of revision has been discussed with authorities in the subject, friends of the late Mr. Gamble and holding high positions in the Fire Service. The consensus of opinion is that the book is so "Gamble" that to interfere with it in any way would be to spoil it.

Old illustrations might have been replaced by new, but since the latter are available in the technical press and in makers' catalogues, and the book is urgently needed, it is reprinted as it stands to avoid further delay.

CHARLES GRIFFIN & CO., LTD.

February, 1941.

CONTENTS.

INTRODUCTION.

PART I.

NATURAL SCIENCE, LEGAL AND GENERAL MATTERS.

CHAPTER I.

CHAPTER II.

CHAPTER III.

PART II.

FIRES.

CHAPTER IV.

CHAPTER V.

CHAPTER VI.

CHAPTER VII.

PART III.

MEANS OF SUPPRESSION. MATERIAL AND PERSONNEL.

CHAPTER VIII.

CHAPTER IX.

CHAPTER X.

CHAPTER XI.

CHAPTER XII.

CHAPTER XIII.

CHAPTER XIV.

CHAPTER XV.

CHAPTER XVI.

PART IV.

FIRE PREVENTION, PANIC, CONSTRUCTION OF BUILDINGS.

CHAPTER XVII.

CHAPTER XVIII.

PART V.

MISCELLANEOUS.

CHAPTER XIX.

CHAPTER XX.

ABBREVIATIONS.

cm.,	centimetre
$cm.^2$,	square centimetre
$cm.^3$,	cubic centimetre
g.,	gramme
kg.,	kilogramme.
km.,	kilometre
$km.^2$,	square kilometre
l.,	litre
m.,	metre
$m.^2$,	square metre
$m.^3$.	cubic metre
mm.,	millimetre
$mm.^2$,	square millimetre
$mm.^3$,	cubic millimetre
C.,	Centigrade
F.,	Fahrenheit
°,	Degrees.
° C.,	Degrees Centigrade
° F.,	Degrees Fahrenheit
%,	Per cent.
+,	Plus, addition
−,	Minus, subtraction
×,	By, multiplied by
÷,	Divided by
$\sqrt{\ }$,	Square root
$\sqrt[3]{\ }$,	Cube root
=,	Equals, equal to, becomes
Log.	Logarithm

[To face p. 1.

THE AUTHOR.

A PRACTICAL TREATISE

ON

OUTBREAKS OF FIRE.

INTRODUCTION.

HISTORICAL NOTES ON THE FIRE SERVICE IN GREAT BRITAIN.

MAN'S destruction was first threatened by the Deluge, and ever since it has been threatened by Fire. In all Ages Man has recognised Fire as one of his most potent enemies. He has been often amazed at its ravages and terrified at its fierceness. In the Dark Ages the awfulness of fire and the fear it aroused was often declared by Sacerdotals to be the expression of the majesty and power of deities, and this is so even to-day in some of the less frequented parts of the World, whilst at all times the God of Fire has been depicted as fierce and unmerciful.

Even to-day, after centuries of social and educational development, when Man can pride himself on his all-conquering progress in harnessing the forces of Nature, when the great victories of science during the last century stand out as a pinnacle of intellectual achievement. Fire reigns with undisputed sway as the greatest destructive agent in the World, against whose strongholds comparatively little headway would appear to have been made.

The destructive power of fire is appalling. The yearly loss by fire in the United Kingdom runs into millions of pounds sterling, though the figures given by various authorities differ widely. The loss, however, is substantial, and, what is more, there can be no question that it is an *absolute* loss. Destruction by fire is a dead loss to mankind even supposing, as is the case in the majority of instances of the present day, the individual sufferer is financially safeguarded by insurance. Monetary compensation can never replace that portion of the World's wealth destroyed by fire. Wealth becomes void under its devouring influence. The work of centuries is soon reduced to little more than a memory. Beautiful buildings, works of art, records and ancient libraries, which would have been a mine of information to the student are for ever sunk in oblivion and lost by the action of fire.

Amron, General of Omar, having taken Alexandria, wrote for directions respecting the disposition of the famous library which it had been the pride of the Ptolemies to collect. The reply was—if the writings agreed with the

doctrines of the Koran, they were useless; and if they did not, they ought to be destroyed. The argument was irresistible and the whole was burnt.

Every year disastrous forest fires occur, whole cities, ships, and valuable cargoes of merchandise are destroyed, and a toll of human lives is gathered.

It has been said that perhaps the social reformer, eager to find money for his reforms, might well turn his eyes to the millions of the country's wealth that are every year vanishing in smoke and flame. But one might, without even thinking of fresh uses for the millions yearly lost, at least concede the point that fire prevention and fire protection should receive more consideration from legislature. The central government might in some way assist in the fight by encouraging the development of prevention and the organisation of an efficient fire-fighting service, not as it exists to-day, in a few scattered municipalities, but as a general service throughout the country.

It is true that the subject of combating fires has, during the last thirty years, received more attention in this country than ever before, but we are still a long way from perfection.

With all the losses which have occurred—and they must total an enormous sum even in a generation—it was only a little over 75 years ago that the duty of extinguishing fires in London was taken over by public authority from the hands of private enterprise.

But some explanation is perhaps necessary here to save the reader from the error of imagining that the first efforts at fire extinction are to be found within the last century. To have such an impression would be unfortunate, and would probably lead him to forget altogether that long struggle which the enthusiasts in the fire service had, before they obtained any consideration and effective recognition by high authorities as an essential and useful department of local government.

The principal reason for the slow adoption of fire brigades and fire services is more than likely to be found in the complete lack of appreciation in the official mind as to their utility. Even to-day a fireman's work is sometimes spoken of as if any man in the street might easily run out a length of hose and turn on the water, and as if that work constitutes the essential business of a fireman. That is where the trouble lies. No greater error can be committed. The technical knowledge required, already complex and specialised, is yearly becoming more so, and as the public get to understand what fire loss really means, and that it could have been prevented, they will appreciate the sterling value of the fireman, and *that it is brains, and not red paint and polished brass*, or a deluge of water that are needed to make a successful fireman.

Fire brigades have existed in one shape or another for centuries. In early history and Roman times they were co-existent with Military government.

An interesting account of a Roman Fire Brigade appears in Vol. 18 of the records of the Royal Archæological Society.

Curfew.—The custom in England of covering up all fires at a fixed time in the evening may date back to King Alfred's reign. The mode of heating buildings at that time was by a wood or peat fire upon a hearth in the middle of the room, the smoke ascending and escaping through a hole in the roof.* The floors were covered with rushes upon which many of the inmates slept.

* These holes, filled in with Louvres, can still be traced in the roofs of ancient halls and kitchens and at the colleges at Oxford and Cambridge.

Therefore, the proper covering of the fire was a very necessary precaution against the embers being blown about amongst the combustible material in and about the buildings. William the Conqueror found it a useful regulation and ordained that it should be rigidly carried out upon the ringing of a bell. In default the offenders were subject to severe penalties.

The covering up of the fire was called by the Normans couvre-feu, which afterwards became curfew, and in course of time the ringing of the bell itself was given that name.

The cover at first may have been similar to a present-day dish cover, but after the introduction of the chimney* the fires would be upon the hearths under the flues, and naturally the best method of covering the embers would be to rake them as close to the back of the hearth as possible and place the curfew in front. Fig. 1 is an illustration of an ornate example of a curfew from Canterbury. It is of copper, ten inches (·2540 m.) high, sixteen inches (·4062 m.) wide and nine inches (·2286 m.) deep; others may still be found in the South of England.

The time of ringing the curfew bell seems to have been eight o'clock in the evening, but in many places the time of tolling was seven, and it was gradually advanced to eight, and, in some places, to nine o'clock.

The absolute prohibition of lights after the ringing of the curfew-bell was abolished by Henry I. in 1100.

Tradition hands down that this salutary police regulation served the important purpose of keeping people within doors after dark and thus preventing nocturnal brawls in the streets. It is also asserted that the severity exhibited by William the Conqueror in enforcing obedience to the curfew law was political and particularly designed to prevent the English from assembling in secret to plot against him or his government.

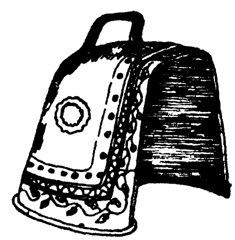


Fig. 1.—Curfew or Couvre-Feu.

The ringing of the "prayer-bell," as it is called in some Protestant countries, undoubtedly originated with the curfew. In Scotland ten o'clock was not an unusual hour.

When the Romans left our shores in A.D. 410 the government of the country languished and fell into decay. There was no power in the land strong enough to give direction to the people's energies, and through the succeeding centuries very little improvement took place. The dormant state of local government in England gave no opportunity for the establishment of any department until the reign of Elizabeth, and it is notorious that up to the time of the Great Fire of London in 1666, siphos or squirts, similar in design to those left by the Romans, were the best implements that were employed in suppressing fire. During the years prior to 1666 the regulations required that "a barrelful of water for quenching fires should be placed before the doors of a building" and the "bellman ring their bells at night,

* Rochester Castle, built in 1130, had complete fireplaces with semi-circular backs and an arch over. The flues, however, go only a few feet up in the thickness of the wall, and are turned out at the back through small oblong holes. A few years later the improvement of carrying the flues up through the whole height of the wall appears.

and call out :—' Take care of your fire and candle, be charitable to the poor, and pray for the dead.' "

Following the disaster of the Great Fire various ideas and schemes were put forward, especially by the Citizens of London, but it is strange that the proposals were directed more towards recuperating themselves for losses than in any direct action for combating and extinguishing fire. It seemed better to have strong insurance companies than strong fire brigades.

The first fire insurance companies made their appearance in 1684 and many more came into being in the next fifty years, but fire brigades were almost non-existent.

On the Continent things were developing along different lines. Whilst in this country insurance companies were everywhere springing into existence, the free cities on the Continent, benefitting, no doubt, by a translation of the works of Hero of Alexandria, published in 1583 with a description of Ctesibius' pump, forthwith expanded and developed the idea, and formed fire brigades to defend their property. This movement was materially assisted by the advanced state of their communal government and by the public spirit of the inhabitants in encouraging inventions.

The advance was indeed enormous. For the previous 1700 years practically nothing had been done, and these inventions prepared the way for the advent of the modern fire brigade.

An excuse might possibly be entered here for the backwardness of English affairs. Indeed, if an attempt at improvement or development had been made it is probable that the efforts would have been futile. Social England was not ready for such things. The Church had long been the only educational institution in the country, and, as is to be seen in the imprint of her work on the local government of England to-day, her influence was enormous.

The Church indeed was a power in the land not to be forgotten, and being naturally somewhat jealous of her position, it is not at all likely that she would have received very kindly any suggestion for the diminution of her power and prestige, nor have been favourably disposed to any alteration or expansion, by the adoption of new ideas. The process was therefore very slow indeed, so slow that it might have been imperceptible to casual observers of the time, who view the gradual developments in things as if they were isolated occurrences without any relation to the whole development and expansion of civilisation.

Then the Reformation came, and with it the enormous expansion in English trade and influence. Social England received a fresh lease of life, but the echoes of the Reformation had hardly died away when the struggle commenced between the King and his Parliament. This was another bar to internal settlement and reorganisation. Even for 100 years succeeding the advent of fire brigades into Continental towns, the local government of this country was unripe for their introduction. The Parochial system savoured too much of ecclesiastical control, and the larger centres generally were too much concerned with the affairs of Court and Parliament to introduce measures for the benefit of their communal existence.

In spite of the lack of efficient internal administration, it is rather difficult to explain why, in the large cities like London, no public organisation had been established for the suppression of fire. Various measures had been

taken from time to time with the object of providing a means of extinguishing or preventing the spread of fire, but it is to be noted that these invariably meant nothing more than that those residing near the scene of an outbreak should provide buckets of water, ladders and axes, etc. There was no body of men specially retained for the exclusive purpose of dealing with fires. It seems to point to the fact that our communities were hardly anywhere established or designed to do more than administer, certainly not to organise and develop in their corporate capacity, and the idea of forming brigades, together with many of the other splendid municipal services which we have to-day, was impossible until some drastic change should come over the scene.

The London Court of Common Council met after the Great Fire of London to discuss the means of preventing future disasters and decided that there should, "in each of the four divisions of the City, be kept 800 leathern buckets, 50 ladders from 12 to 40 feet in length, two brazen hand squirts to each parish, 24 pick axe sledges and 40 shod shovels," and that "the men should be provided from the several companies of carpenters, bricklayers, plaisterers, painters, masons, smiths, plumbers, and paviors who should accompany the Lord Mayor and Sheriffs on all occasions of fire for extinguishing the same."

Interest in this soon died, and during the next 150 years the effort was only supported by a few men with manual engines which were allowed by the parochial authorities to fall into a chronic state of inefficiency. Of course, the fact must not be overlooked that communication was very difficult, and education generally was of a low order, especially on the mechanical and scientific side. Nor indeed, was it sufficiently diffused throughout the country to give any opportunity for the dissemination of information. On the other hand, new ideas were much more prone to be received with that traditional reserve and hesitation which has been our continual reproach, until they were shown to be indispensable to national life.

Whatever the reason may have been, the opportunity neglected by the Community was quickly taken up by the fire insurance societies. They were not long in turning fire brigades to the good of their own account. Public effort was too insignificant to demand serious notice. All the progress that was made took place as the result of private enterprise.

The precise date when fire insurance offices commenced the formation of their own independent brigades is doubtful, Some believe that an organisation was in existence in about 1684, but it is not certain. Various old engravings and prints show engines and appliances, but only in a few cases can dates be discovered. Nor can it be ascertained with certainty how many offices had brigades. It is known that most of them maintained these bodies at their own expense in many of the large towns, and that according to the office in which a building was insured it was the duty of that company's brigade to extinguish any fire which might occur in that building. This accounts for those mysterious plates called "fire-marks" often seen affixed to the walls of old properties.

The advantage of these institutions, though undoubtedly supplying a real want, was if anything, designed to be more beneficial to the shareholders than to the public. Indeed it would have been surprising to have found it otherwise. The peculiar constitution of these brigades fostered competition

and this became the main spring to efficiency.* Rivalry acted as a stimulant to work, and was as much a public advertisement for the companies as it was a safeguard to the interests and property of the people. There can be no doubt that the men were useful, and their work constantly tended to prevent the spread of fire and the increase of fire losses, and operated in the favour of the insurance companies.

This was the system which for nearly 130 years was responsible for dealing with fires in this country.

In 1832 under an Act 14 Geo. III., c. 78, Sections 74, 75, certain parishes in London were required to keep one large and one small engine, a leathern pipe, and a certain number of ladders, without providing means for the payment of any competent persons to take charge of and to work them at fires. Such a law, as was justly pointed out, was so manifestly defective in all points essential to efficiency that it became almost useless. From the best information obtainable it appears that the total annual cost of maintenance to the parishes and districts concerned was not much less than £5,000.

In 1832 the insurance companies doing business in London pooled their brigades and formed the London Fire Engine Establishment, placing it under the command of Mr. James Braidwood of Edinburgh, a surveyor who had achieved success as a fire-chief by re-organising the fire service of that City in 1824.

The London Fire Engine Establishment commenced its duties on the 1st of January, 1833, with the support of ten of the Fire Insurance Companies; these were joined within the first year by two others, making, during the year 1833, twelve Fire Offices maintaining the Establishment. At various times changes took place in consequence of new offices joining, others ceasing to exist, and some few becoming amalgamated; but, on the whole, the number steadily increased, until, in 1864, it amounted to thirty; three offices having amalgamated, left twenty-eight at the end of 1865.

Edinburgh was the first city to possess a whole time professional fire brigade in the United Kingdom, and was followed by Manchester and Glasgow.

Thence onwards brigades began to spring into existence. Liverpool Local Act 1842, 5 and 6 Vict. c. CVI. S. 162, made insurance companies liable, and Manchester obtained a special local Act in 1844 called the Manchester Police Regulation Act, 7 and 8 Vict. c. 40, which empowered the Corporation to maintain out of the Police rate the staff of the Fire Brigade service, etc. London, however, still favoured her private concern and made no apparent effort to effect a change until 1866.

The cost to the Insurance companies of upkeep of these bodies of firemen was at first small, but between the dates of their inception and 1832 it increased considerably. No doubt also competition between the various insurance companies tended to intensify the feeling for reform, but it must

* From rejected addresses pub. 1912 by J. & H. Smith.

"The engines thundered through the street,
Firehook, pipe, bucket all complete,
And torches glared, and clattering feet
Along the pavement flew.
The HAND-IN-HAND the race begun,
Then came the PHŒNIX and the SUN,
The EXCHANGE, where old insurers run,
The EAGLE where the new."

also be noted that the rivalry between the bodies of firemen representing different companies did unfortunately provoke much irritation and difficulty between their controlling companies, and it was not uncommon for the firemen to decide their points of difference by recourse to fisticuffs.

To overcome these difficulties, and doubtless at the same time to improve the system in conformity with the needs of the gradually extending area of buildings and developments of trade, a revision of the system was undertaken.

A year after the formation of the London Fire Engine Establishment, viz., in 1833, a general Act was passed, 3 and 4 William IV. c. 90, which enabled areas wishing to do so, to appoint a body of persons called inspectors to provide and keep up fire engines, etc. Certain parishes in what is now the County of London availed themselves of this Act. This Act, however, was not much better for efficiency than the one of 1774 and was almost as useless for the development of a fire service as it could be.

Such therefore was the state of things when Braidwood was called to organise the new body. He brought with him a trained scientific mind, and an enthusiasm for work. Indeed the writings he has left tell us how deeply he was absorbed in his profession of a fireman. There is no department of the fire service which does not bear the imprint of his genius. He found the London fire service in fragments with a lamentable lack of co-operation and co-ordination. No proper scheme had been laid down to deal with the fire risks of London as a whole. There was considerable overlapping, and consequent friction and extravagance. The great problems which always puzzle the fire brigade officer, viz.: those of rapid concentration and distribution of forces had found no solution whatever. All these matters he took in hand.

To his energy and ability are attributable the great success which attended the work of the brigade during the whole period of his holding office.

He had his difficulties, for it must be remembered he was limited as to funds. All his measures had to have more than usual care in their design, so as not to strain too severely the resources of his private employers. Often he could not realise his ideals for the lack of means. Yet he contrived to protect London and extinguish fires for 30 years without a single question ever being advanced as to duty, right, privilege or responsibility.

But for his untimely death at the great Tooley Street fire on 22nd June, 1861, London might have still further profited by many more years service of this gallant Scotsman.

He was succeeded by Captain Eyre Massey Shaw of the North Cork Rifles, a man with a singular combination of good qualities. He had achieved a reputation before coming to London by his skilful organisation of the Police and Fire Services of the City of Belfast. He was therefore conversant with what would be demanded of him and he was able to bring his experience to bear on his new appointment. He was very popular with all ranks of Society and possessed the common quality of all genuine Hibernians—a good literary style.

But while the majority may be more than anxious to bear testimony to the great work wrought by him, it would hardly be fair to ascribe to him all the great things with which he has been credited. It has been said that Shaw created a new profession. He himself almost claims the credit for it, and he undoubtedly was a shining light in the Fire Service world and outshone during his time any other fire chief. He held sway for over 30 years, but

when all the credit is given it must be said that Shaw was not the first to awaken the public interest in the profession. That honour most justly belongs to James Braidwood.

A few months after the death of Braidwood the Insurance Companies' representatives forming the Committee of Management met to discuss whether any changes were necessary in the Establishment. After deliberating for about five months they made overtures to the Home Office concerning the future protection of London, and in the following February made their position clear by pointing out that they, as the London Fire Engine Establishment, had *no legal status whatever*, neither charter, Act of Parliament, nor deed of partnership; but that, without any public authority whatever, the Establishment had for 30 years extinguished the fires which had occurred in the Metropolis and surrounding districts without inquiry and without charge to the public funds.

The companies had year by year sustained a rapidly increasing expenditure the effect of which had been to relieve parishes and public bodies of the obligations properly devolving on them as regards the extinction of fires.

In 1833 the number of fires attended was 458 and the expenses incurred £7,988. 80 men were employed, located in 19 stations.

In 1865 the number of fires attended was 1,502, the expenses £26,005. 129 men were employed, located in 20 stations.

Such an increase in the number of fires and in the expenditure incurred rendered a reconsideration of the whole subject imperatively necessary, more particularly as the Committee of Management were satisfied that a system for the extinction of fires which might formerly have been adequate for the Metropolis had become very insufficient for its present greatly extended limits.

It was also pointed out that there was not any other capital or extensive city of Europe or America where the fire extinction service was not in the hands of the public authorities, and maintained principally by public rates and taxes, and that this observation also applied to most of the large provincial towns of the United Kingdom, viz.: Liverpool, Manchester, Glasgow, etc.

During these thirty years London had grown considerably, and it was felt that it would be wrong to discontinue a service which had undoubtedly proved its usefulness. And yet the brigade, which had been increased in personnel and equipment since its formation, needed further augmentation to cope with London's increasing wealth and trade. Another question arose, however, which undoubtedly must have weighed heavily with the supporters of the old Establishment. The proposal that the public authority should take over the Establishment revealed an aspect of the Service which had hardly ever entered the mind of the public before. For the companies to maintain this institution for the benefit of their insured clients seemed good, sound business, but subsequent developments seemed to have shifted this privilege, or rather enlarged it, until it included not only those insured, but also those uninsured. It was obviously the reverse of practical business that an insurance company formed to finance their policyholders' risks, should support a movement, the benefits from which were more largely reaped by people who were not their clients; and that the uninsured should receive protection for which they had not contributed anything in the form of insurance premiums.

Ultimately the companies signified their intention of closing down the

Establishment, and suggested through the Home Office that the Metropolitan Board of Works should take the opportunity of acquiring it.

This proposal at once laid bare another extraordinary situation. No general Act of Parliament existed which enabled a governing body to raise money for the purpose of forming a fire brigade, and when the Metropolitan Board of Works desired to take over the London Fire Engine Establishment, a special Act had to be obtained for the purpose, known as the Metropolitan Fire Brigade Act 1865. This Act included the City of London.

Such Acts as had been passed prior to this dealt only in a piecemeal way with the maintenance of appliances but not with any other means of developing efficient protection. The House of Commons referred the question to a Select Committee, and their deliberations resulted in the short, simple and effective Metropolitan Fire Brigade Act 1865. Accordingly, on the 1st January, 1866, most of the officers, men, and appliances of the Establishment were taken over by the Metropolitan Board of Works, and the few parochial authorities who had maintained manual fire engines ceased to do so. The new organisation was called the Metropolitan Fire Brigade.

It might here be pointed out that the fire service had up to this time been confined almost exclusively to the side of fire extinction, and the saving or protection of life had formed only an additional duty to that for which the brigade primarily existed.

The duty of saving life at fires had been undertaken by the Society for the Protection of Life from Fire which was founded in 1836. It was supported by voluntary contributions, and provided and maintained fire escapes and men in London and various large provincial towns. The Society also rewarded rescuers with money and medals.

On the 1st July, 1867, most of the 85 escapes and attendants in London were taken over by the Metropolitan Fire Brigade, and in 1880 the escapes stationed in provincial centres were presented to the respective municipalities.

This Society is still extant at 20 New Bridge Street, London, E.C., but its activities are confined only to granting rewards and medals for bravery at fires.

From 1st July, 1867, the Metropolitan Fire Brigade became the sole authority in London for the protection of life and property from fire. Its Headquarters were situated in Watling Street, but were later (1878) transferred to the present location in Southwark Bridge Road, London, S.E.

Funds to maintain the brigade were provided as follows:—

1	A contribution from the Fire Insurance Companies of £35 per million of the gross amounts insured by them for property in London estimated at	£10,000
2.	A yearly contribution by the Government of . . . (this sum is still paid).	10,000
3.	The produce of a halfpenny rate on all rateable property in London, estimated at	30,000
		£50,000

No. 1 was suggested as being similar to the assessment laid down in the Manchester Act, 1844.

This sum of £50,000 was deemed by the Board sufficient to meet the expenses of the adequate protection of London. Shaw, however, never concurred in that opinion. He provided for a personnel of 575; four floating steam fire engines, 72 land steam fire engines, and 54 manual engines, with horses and drivers, distributed among 54 large, and 103 small fire engine stations over the area of about 117 square miles. This scheme he considered would be thoroughly effective under all ordinary circumstances, although unable to cope successfully with those exceptional calamities which occasionally befall all great cities, but which, owing to its great wealth and population, and the vast requirements of its trade, are much more likely to happen in London than elsewhere.

From this period the history of the Fire service to a great extent centres round the history of the London Fire Brigade.

Shaw did not confine himself within the limits of fire extinction and life saving at fires, but ventured into the wider and almost unexplored field of fire prevention. He published treatises on many aspects of the work, and was called upon on several occasions for his opinions on abstruse questions connected with the profession. Under his influence and the awakened public interest, the fire service expanded and became an important department of the municipal service.

In 1889, under the Local Government Act, 1888, the Metropolitan Board of Works ceased to exist, its functions being transferred to the London County Council. The Metropolitan Fire Brigade, therefore, found new masters. On the 31st December, 1888, the Brigade comprised 59 stations and 674 men. The number of stations and plant were admittedly insufficient. As has been shown, the scheme laid down nearly 30 years previously was more extensive, but had never been carried out in its entirety. The reason for this was that the financial powers of the Metropolitan Board of Works under the new Act were limited to a sum equal to a rate of one halfpenny in the pound upon the combined rateable value of the property in the Metropolitan Board of Works' District and the City of London. By the transfer the Council was freed of this difficulty, and hence-forward the brigade was expanded in a manner that the Board could never have aspired to.

Ever since, the fire service has steadily grown in public favour, and it has been extended so that it now includes fire prevention as well as the original extinction service. Fire prevention is being more and more recognised as equalling, if not exceeding, in importance, the older part of the service, thereby, unconsciously perhaps, but nevertheless, fulfilling the old adage that "prevention is better than cure."

Unions and Associations.

The Fire Brigades Association.—The impetus given to the study of fire protection and fire prevention by the trials of manual fire engines at the Exhibition of 1862, the tests of the steam fire engines at the Crystal Palace in July, 1863, and the agitation for the conversion of the London Fire Engine Establishment into a public organisation, attracted the notice of many leaders of court and society, with the result that an interest was awakened which spread throughout the country and caused the reorganisation of many old brigades and the establishment of new ones.

About the same period the Rifle Volunteers came into being, and under the stimulus imparted to voluntary service, fire brigades became staffed with active and zealous men, many of good social standing, anxious to learn the details of the duty they had undertaken. They began to search for information as to the methods of fire extinction, and, like Braidwood, searched in vain. Such writings did not exist. In other words, no one, excepting the men who had worked the greater part of their lives as firemen, knew " the ropes," and nowhere was their work properly chronicled.

Therefore it was felt that an organisation of some kind was needed to act as a medium for the interchange of ideas and opinions.

Mr. Footit, of Marlow, one of the moving spirits of the Fire Brigades of the Upper Thames Valley and Chief Officer of the Marlow Fire Brigade, together with Lt.-Col. Sir Chas. Firth, who had raised a Volunteer Artillery Battery from amongst the employees at his works at Heckmondwike in Yorkshire, and who also had the advantage of having worked with the Paris Fire Brigade as a Volunteer fireman, proceeded in the early part of 1877 to form an association of fire brigade officers called The Fire Brigade Association.

The following *résumé* of the First Annual Report, dated 31st December, 1877, is, by the courtesy of the Editor of " The Fireman," given sufficiently fully to explain the aim and scope of the association :—

" Your Council, in presenting their first annual report of this association for the year ending 31st December, 1877, acknowledge with great pleasure and thanks the contribution of those gentlemen who have so materially assisted them. To the honorary officers and the committee their thanks are due, and are hereby given for the valuable labour and assistance rendered by them in the establishment of this association, and also to the numerous fire insurance companies and officers of the respective fire brigades throughout the country, for the willing and prompt responses made to us in seeking from them valuable information. As hitherto, the entire work of your Council has been restricted to the formation of the association, providing laws, bye-laws, and regulations and doing the multitudinous and laborious business incidental thereto : we do not, therefore, purpose making a lengthy statement upon our own acts, but to give with the utmost brevity a summary, so as to place before the members of the association a knowledge of its commencement, progress and present position. On Monday, February 5th, 1877, Mr. C. M. Footit, of Marlow, addressed a circular to about 100 Volunteer fire brigades, inviting them to co-operate with him in forming an association. To his circular several fire brigades replied favourably. In the following month he sent a second circular, with a draft copy of the rules, and stated the proposed object of the association. A preliminary meeting was then held in London at the Golden Cross Hotel on the 16th of May last, Captain G. R. Wykeham-Archer in the chair, when it was resolved that it was expedient to form an association, and that another meeting be held on the 5th of July following, which accordingly took place at the Midland Grand Hotel, when several gentlemen interested in the movement attended, and a committee was formed to take such steps as they might deem necessary to organise an association of the volunteer fire brigades of Great Britain. The following gentlemen were then elected to serve on the committee, with power to add to their number, viz. : Colonel Sir Chas. Firth, Captain G. R. Wykeham-Archer, Lieut.-Colonel A. Hill, E. Armitage, Esq., J.P., Captain H. W. Nicholson and Messrs. Barber, Buckland, Carter, Drew, Ellis, Footit, Fuller, Henry, Hodges, Nickalls. Shean, Smith, Stocken, Trendall, and Wilmot. About £200 was subscribed at this meeting towards preliminary expenses. At the first committee meeting on the 16th July it was decided that officers of all fire brigades throughout Great Britain and Ireland, whether of paid, volunteer or private brigades, should be eligible to become members of the association. Colonel

Sir Charles H. Firth was unanimously elected president: C. M. Footit, Esq., hon. treasurer, Messrs. Chappel and Gibbons, hon. solicitors; Messrs. Ransomes Bouverie & Co., bankers; and Mr. G. K. Sorry, Secretary. It was also determined that offices be taken at 8 Craig's Court, Charing Cross, London, S.W. At the following committee meeting on 26th July, it was decided that the name of the association be "The Fire Brigades Association," and the seal and badge of the association was also adopted, and ordered to be registered, which has been done accordingly. At the following meetings held on the 25th September, 8th and 15th October and the 3rd and 16th of December, a prospectus, rules and bye-laws have been drawn up. We have issued about 13,000 circulars through the post to the different towns throughout the United Kingdom of Great Britain and Ireland, but are yet unable to state precisely the numbers of addresses of brigades obtained, but think we shall have about 1,000. In conclusion, your council trust in the continuance of services of their coadjutors in this good work, and appeal to the support of all officers of brigades in furthering and strengthening the position of our Association, and they have also confidence in urgently entreating the general public especially to contribute subscriptions and donations for the benefit of the firemen, whose arduous services and, when demanded, their lives even are placed, as it were, at its disposal. We are confident that the public to whom we make this last part of our appeal is able to appreciate and ever generous to reward."

This association undertook many important duties, and one of the chief was the inspection of factories from a fire point of view. When it is remembered how bad were the conditions of factories just prior to the advent of the Factories and Workshops Act, the utility of this work can be better estimated.

This association also kept in active work for about 10 years the enthusiasm for efficiency, but after that, interest seemed to evaporate and, owing to the difficulties—chiefly financial—which arose, the society began to decline. Towards the end, their work was largely supplanted by the official work of the Home Office Administration. The President himself undertook many of the last inspections and eventually went from town to town carrying out the work and drawing the fees.

Strong endeavours were made, in which the present writer played a part, to revive interest in the association, but without success, and the society languished and died after a life of about 12 years.

It had not existed in vain, for, although it had but followed the way of all things born of an over-excited imagination, it had paved the way for other similar bodies which soon arose from its ashes.

The National Fire Brigades' Union.—On the 15th September, 1887, at a large meeting of Fire Brigades at Oxford to celebrate Queen Victoria's Jubilee, the National Fire Brigades' Union was formed, Alderman Thomas Green, Chief Officer of the Oxford Fire Brigade being elected Chairman, and Henry Turney, Chief Officer of the Stourbridge Fire Brigade, hon. sec. At the end of the first year 70 brigades had joined, and Captain E. M. Shaw, Chief Officer of the Metropolitan Fire Brigade, consented to accept the Presidency of the Union.

The annual reports explain how the Union has extended its work, until in 1924 it numbered 816 brigades, distributed over 16 Districts, each with its own Executive Council. It also numbers many foreign and Colonial correspondents.

Its principal officers were:—

Presidents.

1887 Capt. E. M. Shaw.
1892 Sir E. M. Shaw, K.C.B.
1896 The Duke of Marlborough, K.G.
1910 The Earl of Londesborough, K.C.V.O.
1917 The Earl of Denbigh, C.V.O.
1924 Lord Ampthill, G.C.S.I., G.C.I.E., etc.

Chairmen.

1887 Alderman Thomas Green (Oxford).
1891 Major G. M. Seabroke, F.R.A.S., D.C.L. (Rugby).
1918 Hedley Peters, J.P. (Sittingbourne).
1925 Frances Corby (Bedford).

Hon. General Secretaries.

1887 Henry Turney (Stourbridge).
1888 Archibald Treadaway (Ashton Manor).
1890 Sidney G. Gamble. C.E., F.S.I. (Grantham).
1892 Horace S. Folker (Guildford).
1907 Augustus Hill (Bedford).

Secretaries.

1912 Augustus W. Slater (London).
1918 William Geo. Webster (London), present Secretary.

The work of this body has been in the highest degree creditable to its founders. It has carried on a work in a voluntary and co-operative manner which would have proved an expensive undertaking for any government department. It has spread itself out by the aid of correspondents so that it possesses information of the service in nearly all the countries of the World. Its offices are at 8 Waterloo Place, Pall Mall, London, S.W. 1.

One of the outstanding features of the work carried on by the National Fire Brigades' Union was the inquiry which it instituted in 1898-9 with a view to obtaining from Parliament an Act to :—

I. Regularise fire brigade practice.
II. Obtain exclusive right to the use of firemen's uniforms.
III. Stamp out bogus brigades.
IV. Establish a school whereby fire brigade officers could receive efficient training.
V. Elevate the status of the fireman and his profession.

They so far succeeded that a Bill was introduced by Guy Pym, Esq., M.P., in 1899. It was referred to a Select Committee but it did not become law, although it brought to light the irregular and haphazard methods by which fire brigade work was struggling for life. This Bill also brought to light the many undesirable features in the established services which it was the hope of genuine firemen to eliminate.

The Union was incorporated in 1912 and the name changed to The National Fire Brigades' Association in 1919. The B.F.P.C. was amalgamated in 1924.

The British Fire Prevention Committee.—In 1897 another body called The British Fire Prevention Committee was founded. This Committee carries out a great variety of scientific tests, and has published records of its work in an imposing set of " Red Books " on investigations into different branches of fire work. The Committee has prospered by the very fact of filling the long-felt want of a society which could more or less standardise the qualities of substances as viewed by the fireman, architect and builder, and also as a source of reliable and unexaggerated data on fire protection questions. By its issue of suggestions and " Warnings " it has earned for itself a world-wide reputation and influence. More particularly is the work appreciated from the fact that the tests are carried out by voluntary workers, and many of the Committee have extended a munificence to enable the work to be undertaken that could only be expected from those whose whole heart was in the movement.

This Committee was incorporated in 1899.

The offices of the Fire Prevention Committee are at 8 Waterloo place, Pall Mall, S.W. 1.

The most ambitious undertaking of the Committee was undoubtedly the organisation of the International Fire Prevention Congress in Westminster, and the Fire Exhibition at Earl's Court in 1903. It was justly claimed that never before in any country had architects, engineers, surveyors, municipal officials, legislators, insurance officials and fire surveyors met in Council with professional and volunteer fire brigade chiefs and salvage corps officers: and never before had the papers and discussions ranged over so wide a field as they did during the four days of the proceedings of the six sections into which the Congress was divided.

From nearly every country in Europe, from a large number of other countries so far apart as Chili and Persia, from all the British Colonies, Municipalities, Universities and Scientific Societies, delegates to the number of 705 were sent to deliberate and discuss the work of Fire Prevention in its relation to science and trade. So important were the proceedings considered that they were embodied in an official report of over 200 pages, and a profusely illustrated record of the Exhibition was issued which is worthy of careful study.

Chairmen of the Executive.

1897 Edwin O. Sachs, F.R.S.Ed., Architect, from the beginning up to his death on September 9th, 1919.

1919 Robert Mond, M.A., F.R.S.Ed., F.C.S., etc.

Gen. Hon. Secretary.

Ellis Marsland, F.R.I.B.A., etc., District Surveyor.

Offices.

8 Waterloo Place, Pall Mall, London, S.W. 1.

Testing Station.

St. John's Wood Road, London, N.W. 8.

On the 19th January, 1921, a Royal Commission was appointed "to inquire into the existing provision for (1) the avoidance of loss from fire, including the regulations dealing with construction of buildings, dangerous processes and fire risks generally, the arrangements for inquiry and research and for furnishing information and advice to public authorities and others on matters relating to fire prevention, and (2) the extinction of outbreaks of fire, including the control, maintenance, organisation, equipment and training of Fire Brigades in Great Britain, and to report whether any, and if so what, changes are necessary, whether by statutory provision or otherwise, in order to secure the best possible protection of life and property against risks from fire, due regard being paid to considerations of economy as well as of efficiency."

The Commission held 89 meetings and reported on the 20th July, 1923. The printed report is of 273 pages with maps.

No official action has so far been taken upon the labours of the Commission.

It became apparent, on the issue of the report of the Royal Commission on Fire Brigades and Fire Prevention, that the work of the B.F.P.C. would become more difficult to carry on as a separate organisation, and the research work, which was its most important section, would fail from lack of financial support, especially as there was no indication from the report that this help would be afforded. It was therefore considered expedient to amalgamate the activities of the National Fire Brigades' Association and the British Fire Prevention Committee.

The resolution to wind up voluntarily the British Fire Prevention Committee was passed at meetings held on May 16th and May 30th, 1924, and the premises, library, stock of Red Books, etc., were purchased by the N.F.B. Association.

The research work of Fire Prevention is to be carried on by a special committee of the Association in a similar manner as undertaken by the B.F.P.C.

The Association of Professional Fire Brigade Officers of The British Empire.—Another body of firemen was formed in March, 1902, known as the Associ-

ation of Professional Fire Brigade Officers of the British Empire. Its objects are set out as follows :—

To promote the interests of municipal fire brigades, and to that end to bring their officers into closer relationship with one another : to promote the general advancement of the fire service, and to facilitate the exchange of information and ideas on the subjects of common interest to members of the association and others.

The name was changed in July, 1920, to the Professional Fire Brigades' Association.

Its present Secretary is Mr. J. T. Burns, Chief Officer of the **Birkenhead Fire Brigade**.

It has upwards of 500 members and associates.

Presidents.

1902 J. J. Thomas, Liverpool Fire Brigade.
1903-1904 W. Paterson, Glasgow Fire Brigade.
1905 J. Scott, Bradford Fire Brigade.
1906 W. Ely, Leicester Fire Brigade.
1907 J. J. Thomas, Liverpool Fire Brigade.
1908 S. M. Eddington, Tottenham Fire Brigade.
1909-1912 Lt.-Col. C. J. Fox, London Salvage Corps.
1913 W. Inkster, Aberdeen Fire Brigade.
1914 J. H. Blezard, Barrow-in-Furness Fire Brigade.
1915 A. R. Tozer, Birmingham Fire Brigade.
1916-1917 A. Pordage, Edinburgh Fire Brigade.
1918-1919 J. T. Burns, Birkenhead Fire Brigade.
1920 J. Scott, Bradford Fire Brigade.
1921-1922 H. Neal, Leicester Fire Brigade.
1923-1924 J. W. Dane, Croydon Fire Brigade.
1925 J. Farmery, Ilford Fire Brigade.

International Fire Service Council.—This body was founded in Paris on 12th August, 1900, on the occasion of a meeting of fire brigade officers from almost every quarter of the globe.

The object was to form a permanent association for :—

1. The development of the fire service.
2. The general improvement of that service.
3. The defence of its interests.
4. The study and propagation of methods of preventing fire.
5. The entertaining of friendly international relations between the individuals affected.

The first President was Count Kamorowsky, the official representative of the Société Imperiale des Sapeurs-pompiers Russes.

The office-bearers were :—

	President.	*Treasurer.*		*Secretary.*
1900	Count Kamorowsky.	Capt. Rauter.	1903	G. de Marie, Luxembourg.
				Lt. Henry.
1903	J. Meier, Amsterdam, died 1920.	Capt. Philips, of Termonde, died 1924.	1909	Capt. Welsch, Ghent.
			1913	M. Staudt, Prague.

The Council met in session in 1900 at Paris.
1903 ,, London.
1904 ,, Budapesth.
1906 ,, Milan.
1908 ,, Luxembourg.
1909 ,, Amsterdam.
1910 ,, Brussels.
1912 ,, St. Petersburg.

The arrangement was for the Congress to be held at least triennially at different cities.

The Headquarters of the Council is now definitely located at Amsterdam.

In the early days of the Council the chief work carried on was the interchange of experiences and small reports on notable fires. In 1911 a very comprehensive report on the investigations by the British Fire Prevention Committee as to the results of 58 tests on shutters and doors of different kinds was compiled in French and German and circulated. In 1912 an international dictionary of terms used in the fire service was collated and was nearly ready for publication when the work was abruptly interrupted by the Great War of 1914, and has not as yet been resumed since the signing of Peace.

The Institution of Fire Engineers.—Yet another organisation was considered desirable by those interested in the promotion of the science and practice of fire engineering. The Institution of Fire Engineers was founded in 1919 and Incorporated 1924 for the express purpose of dealing with the intellectual or educational aspect of the science, with a view to stimulating and encouraging aspirants in the fire services to graduate in the profession by examination. By this means it is hoped to assist municipalities in their selection of officers qualified for the position of fire chiefs, etc.

This concludes the large array of associations which have grown out of the enthusiasm of fifty years ago. By their past record, granted the same spirit is kept aflame, and there is every indication of that, the future should be even more productive of good work.

Ancient Idols of Firemen.

THE EGYPTIAN FIRE-GODDESS SEKHET, *see Frontispiece.*

Upon a door from the Temple of Jupiter preserved in the Museum at Lyons is an inscription indicating that **Titus Flavius Latinianus,** Prefect of the Night-Watchmen, had been created a Vigilium or protector of the gods and goddesses, after an outbreak of fire from which the City was happily saved.

Sts. Barnabas and **Elias** have been considered as Patron Saints of Firemen. In art St. Barnabas is portrayed with flames or a stake, in allusion to his martyrdom. St. Elias, who brought down fire from Heaven, has recently been also chosen as the Patron Saint of Flying men.

Saint Florian was born at Enns, in Lower Austria, and, though a Christian, became a Roman soldier. Many miracles are recorded of him ; in particular, that he once extinguished a great fire with a single pitcherful of water. He finally suffered martyrdom by being tied to a stone and thrown into the River Enns.

The symbol by which he is distinguished in art is a figure throwing water on a burning house.

On 6th July, 1489, Jean de Facuet bought a piece of ground on the flank of the Rohan-Marche-Bran, near de Facuet. He built a chapel to the honour of Saint Barbe.

Saint Barbe is a very popular Saint in Brittany, where she is regarded as the special patroness of firemen. At their annual dinner, held on her day, her statue, surrounded by flowers, is placed at the head of the table.

Part I.—NATURAL SCIENCE, LEGAL AND GENERAL MATTERS.

CHAPTER I.

AIR, WATER, FIRE.

Air, Water, and Fire, together with Earth, were the only so-called "elements" known to the Alchymists of old—the forerunners of the comparatively modern Chemist. The Druggist of to-day often perpetuates the tradition by exposing his brilliantly illuminated show bottles of gorgeous coloured solutions, upon the outsides of which are painted symbolic signs representing the heavenly bodies, such as

☉	= The Sun	= yellow (gold).
☽	= The Moon	= silver.
☿	= Mercury	= quicksilver.
♀	= Venus	= copper.
♃	= Jupiter	= tin.
♂	= Mars	= iron.
♄	= Saturn	= lead.

This "element" theory has been exploded long ago. To-day it is known that Air, Water and Earth are compounds or mixtures of many elementary substances, and that Fire is merely a change of state or condition.

Although the Earth may be omitted, as it has no direct bearing on the present subject, Air, Water, and Fire play such a prominent part in the daily life of all that a close acquaintance with their characteristics, properties, and compositions is desirable, if not indeed essential to success. Before considering them with particular reference to their bearing on the Profession of a fireman, some information of a general character will be found useful.

Everything that can be seen, felt, tasted, or smelt, is known as "matter" or "substance."

All substances consist of one, or a compound of any two or more, of eighty-three elements or simple substances. This number is subject to increase or diminution with the progress of the Science of Chemistry. Oxygen, Hydrogen, Nitrogen, Carbon, Silicon, Aluminium, Magnesium, Calcium, Sodium, Potassium and Iron are the Elements most frequently met with, and together form 99 per cent. of the Earth's crust.

Substances are not perfectly continuous, but consist of an immense number of very small particles known as "atoms."* These atoms are so

* Recent research tends to show that, although the atom still remains supreme as a basic unit because it is the smallest mass that will enter into chemical combination, it is itself built up of still smaller components known as "electrons."

small that they cannot be further artificially subdivided. They are retained side by side, without touching each other, and are spaced at distances, which are great when compared with their infinitely small dimensions. The smallest masses of substance or matter that we are able to obtain by artificial means are called "particles," and are enormously great when compared with "atoms." Generally speaking, two or more "atoms" form a group known as a "molecule" (a definite structure corresponding to a definite substance), although with certain substances termed *monovalent*, "atoms" and "molecules" are identical. Substances consequently consist of an aggregate of "molecules," and these again are built up of still smaller "atoms." Molecules remain in position by the action of certain forces known as "molecular forces." Lord Kelvin calculated that in an ordinary substance the distances between neighbouring molecules lie between the extremes of one hundred-millionth and one two-thousand-millionth of a centimetre, and, to give a conceivable idea of the size of molecules, worked out the following examples :—"If you could take a drop of rain the size of a pea, and magnify it to the size of the earth, increasing the size of its composing molecules in the same proportion, then the structure of the mass would be coarser than a heap of fine shot, but probably not so coarse as that of a heap of tennis balls."

The molecules of bodies, substances, or matter present themselves in three different forms of aggregation—

(*a*) The solid state, such as earth, metals, wood, etc.
(*b*) The liquid state, such as oil, water, alcohol, etc.
(*c*) The gaseous state, such as the air or atmosphere, coal gas, Hydrogen, etc.

Solid substances tend to preserve their size and form until force is expended in altering the relative positions of their composing molecules.

Liquid substances retain their bulk but not their form. In liquids molecules move with great ease and, gliding past each other, permit the substance to readily adapt itself to the form of any containing vessel, whereas in solids the relative position of the molecules is fixed.

Gaseous substances are characterised by a still greater mobility of their molecular composition, whereby they lose the property of a definite bulk or form, and, by reason of the property called elasticity, which they possess in a marked degree, always tend to expand or occupy a greater space. There is, however, reason to believe that this property of elasticity is not without limits.

Many bodies may be made to pass through all three stages, water perhaps furnishing the most familiar and best example, as ice, rain, and vapour.

All matter is possessed of certain general qualities, such as impenetrability, extension, divisibility, porosity, compressibility, mobility, and inertia; whereas specific qualities, such as solidity, fluidity, tenacity, ductility, malleability, hardness, transparency, colour, etc., serve to define a particular substance.

Matter is subject to the action of Natural Forces, the laws of which have been laboriously pieced together by centuries of patient research. The principal of these forces are gravitation, heat, light, sound, magnetism, and electricity.

It is thought that, through the agency of an omnipresent, all pervading,

elastic fluid known as "ether," these forces transmit to the ultimate atoms of matter definite vibratory motions varying in character and velocity. Thus a motion of a particular kind when communicated to the "ether" gives rise to the phenomenon of Heat, and a motion of the same kind, but of greater frequency gives rise to Light. It is probable that another "ether" motion, different in form and character, is the cause of Electricity. The vibration of atoms of bodies communicate motion to the ether and this fluid, which penetrates into the innermost recesses of the inter-atomic spaces of matter, can also impart motion to the atoms. Consequently the atoms of bodies are both the sources and the recipients of the motions of vibrations of the ether, and all physical phenomena are but transformations of this motion.

Air.—The Air, or layer of gases which surrounds the Earth and is carried along with it, is known as the "Atmosphere," a term derived from the Greek word "*atmos*" (gas), which signifies literally a sphere or globe of gases. By recent researches the existence of the atmosphere has been recognised up to a height of at least 100 miles.

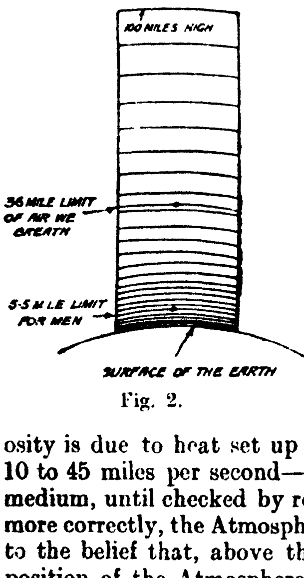


Fig. 2.

At that immense height it is, of course, of great tenuity; in fact, it is near the extreme limit of its elasticity or power of expansion. An idea of the great rarity of the upper regions of the Atmosphere can be gathered from the fact that at the comparatively small height of only 5·5 miles it is already so rarefied that Man cannot live without additional Oxygen supplied by artificial means. The estimate of height of the Atmosphere has been arrived at by the observation of meteorites (bodies falling to Earth from space—perhaps from the Moon) and auroræ (luminous electrical phenomena taking place in the higher aerial regions). At a certain height above the Earth, meteorites become luminous. It is known that this luminosity is due to heat set up by friction caused by the immense speed—from 10 to 45 miles per second—at which the falling body rushes through some medium, until checked by resistance. This medium is thought to be Air, or, more correctly, the Atmosphere, because the scientific opinion of to-day tends to the belief that, above the height of about 36 miles, the chemical composition of the Atmosphere is radically different from the Air we breathe, and consists mainly of the inflammable gas Hydrogen, which is incapable of supporting life.

The Air or Atmosphere, although invisible, tasteless, and without smell, is nevertheless a definite substance formed of an agglomeration of atoms and molecules in just the same way as wood, iron, water, or even the whole Earth itself. As a substance it has all the general and some of the specific qualities of matter. For example, it has weight. Under standard conditions of temperature and pressure (0° C. and 760 mm. of mercury pressure) Air is 773 times lighter than water.

Air is impenetrable, and as a definite substance it occupies a certain space to the exclusion of all other bodies. In other words, it cannot occupy at the

same time the place of another substance, and if for example a solid substance is placed in a vessel filled with a fluid substance, a portion of the latter is displaced and must overflow to give room for the former.

If you dip a cork into a wine glass filled with water, the volume of that liquid displaced by the cork overflows. If you empty away the water and again dip the cork into the wine glass, nothing visibly happens, but, all the same, the cork displaces a quantity of invisible air equal to its own volume. Again, if you invert the apparently empty wine glass and immerse it up to the stem in a large tumbler three quarters full of water, you will see that the liquid does not rise to fill the wine glass although the water level in the tumbler is considerably raised. This displacement of water and the remaining apparently empty space in the inverted wine glass, demonstrates the presence of an invisible something, which something is Air, and although not apparent to the eye is a real and ponderable substance. Now if we look again more closely we shall see that the water rises a small distance within the inverted wine glass. What does this tell us? Simply that the slight pressure exerted by the column of the water measured from the edge of the wine glass to the surface of the water in the tumbler, has been able, in a small degree, to reduce the volume of, or compress into a smaller space, the confined Air. Indeed, in common with all the gases or mixtures of gases, Air is highly compressible, and can be liquefied if subjected to a pressure of 585 lbs. (39·6 atms.) per square inch and a temperature of —141° C. This liquid if placed in a well insulated flask, open to the Air, "Boils" at the very low temperature of —190° C. Liquid Air is referred to in Chapter XII.

Air, as a fluid substance, offers very considerable resistance to moving bodies. This resistance for moderate speeds is proportional to the square of the velocity—*i.e.*, with twice the speed there is four times the resistance. When travelling fast, this resistance is very noticeable, and it is due to its action that Airmen can descend safely from great heights by means of a parachute. It is air resistance that breaks up and damages our fire streams, and finally, were it not for the existence of this resistance and the action of Gravity attracting matter to the Earth, there would be nothing to oppose the perpetual motion of bodies, and a stone, once thrown, would continue onwards in a straight line at the same speed for all time.

Thus, Air, although invisible, is a distinct, ponderable fluid substance, and, when compressed under suitable temperature conditions, finally becomes a liquid. Compression, or the squeezing together of the molecules of a gas requires a definite amount of work. This work is manifested by the generation of heat in the process. Inversely, expansion to the original volume requires the expenditure of exactly the same amount of heat or work, and as this heat is subtracted from the gas itself, or any surrounding medium with which it is in contact, the result is a strong cooling action. Careful reasoning and experiment have discovered the physical law describing the behaviour of Air and gases generally, when expanding or occupying a larger volume. This law, which, although of great practical use, is only approximately true, is named after its discoverer, Boyle's Law. It is :—"At the same temperature the volume of a given quantity of gas varies inversely as the pressure it sustains." In other words, if we take a cubic foot of Air and subject to it double the ordinary pressure, maintaining a constant temperature, it becomes one-half of a cubic foot, inversely, if we desire to expand our

cubic foot of air, to two cubic feet, we must reduce the pressure by half, always maintaining a constant temperature.

This question of temperature is of the utmost importance, because temperature influences that general property of matter known as molecular attraction or cohesion, which tends to maintain united, within their very limited spheres of mutual attraction, the composing molecules of bodies. Heat not only loosens this cohesion, but also accentuates the moving force by which molecules tend to separate in all directions.

The metal zinc furnishes us with a good example of the action of heat in breaking down molecular attraction. This well known metal, solid at ordinary temperatures, when subjected to heat melts and becomes a fluid; if the heating is continued, cohesion breaks down still further and the fluid passes into vapour.

We have seen that cohesion is greatest in the case of solids, and least of all with Air or gases, which indeed, practically speaking, do not possess it at all, whereas they possess the moving force or tendency to expansion in a very marked degree.

Air, like other gases, expands or contracts 0 00367 of its volume for every degree Centigrade of change of temperature, and as this property of expansion or contraction exerts its influence by increasing or decreasing the pressure, it follows that if we wish to expand or compress air or gases to a fixed volume and pressure then we must maintain a constant temperature.

This influence of temperature on the volume of air and gases may be roughly demonstrated by a child's balloon, which has become flabby by diffusion or loss of gas through the pores of the so-called gas-tight fabric. If it is exposed to the warm rays of the sun or to the radiant heat of a fire, it swells up again, and, by an evident increase of pressure, becomes quite hard. On taking it away from the source of heat in a short time it again contracts and returns to its flabby condition, with an equally clear loss of pressure.

It has been already stated that if air is subjected to double the pressure at constant temperature it occupies half the space, or that if half only of the original pressure is applied, always with constant temperature, it occupies double the space; but this is really the same quantity of Air, therefore in the first case a sample taken from it is denser or heavier, and in the second case of lesser density, or lighter than a sample of equal volume taken from the original Air.

As the Air or Atmosphere is a substance with a definite weight and an immense height, it is evident that it must weigh or press heavily upon the earth and all objects on it.

To demonstrate the existence of this atmospheric pressure, Otto von Guericke, the Burgomaster of Madgeburg, devised a simple apparatus, which with slight modifications, and under the name of the "Magdeburg Hemispheres," is made use of to this day. The apparatus (see Fig. 3) consists of two hollow metal hemispheres of 4-inch internal diameter, the edges of which are coned male and female, made to fit accurately, and well greased. One of the hemispheres is provided with a stopcock by which it can be screwed on to an air pump, and the other is fitted with a handle. As long as the hemispheres contain Air, they can be separated without difficulty, because the external pressure of the Atmosphere is counterbalanced by the same

pressure acting in the interior. When, however, the air in the interior is pumped out by means of an Air Pump, and the stopcock closed, the hemispheres can no longer be separated except by very considerable effort, and as this is the case in no matter what position they are held, it follows that the Atmospheric pressure not only exists, but is also equally transmitted in all directions.

The Magdeburg Hemispheres clearly demonstrate the existence of atmospheric pressure, but give no indication as to intensity. To establish this, a great searcher after truth, Torricelli, a pupil of the immortal Galileo, as far back as 1645 carried out the following experiment for the first time.

A glass tube (Fig. 4) was taken, for convenience in handling about 1 yard (0·91 m.) long and $\frac{1}{4}$-inch (0·006 m.) in internal diameter. The tube was carefully sealed at the bottom end by fusion, and then, whilst held vertically, completely filled with mercury, care being taken to expel all the Air. The open end of the completely filled tube was then closed by the thumb, the tube inverted, immersed a short distance in a shallow bowl filled with mercury, and the thumb removed.

Fig. 3.

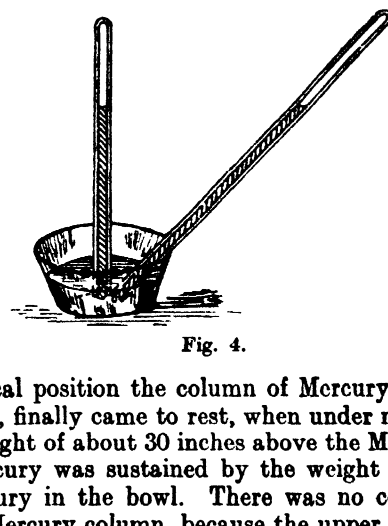


Fig. 4.

The tube being now in a vertical position the column of Mercury sank, and, after oscillating for some time, finally came to rest, when under normal conditions and at sea level, at a height of about 30 inches above the Mercury in the bowl. The column of Mercury was sustained by the weight of the Atmosphere pressing on the Mercury in the bowl. There was no counter pressure acting on the top of the Mercury column, because the upper end of the tube was carefully sealed, and the Air was expelled by the operation of filling, thus leaving a nearly perfectly empty space, known as a "vacuum."

This experiment gives a clear measure of the pressure of the Atmosphere, namely, it will balance a column of Mercury 30 inches (0·76 m.) high, and that height is not altered if the tube is inclined at various angles to the vertical. It will be found that the vertical height of the top of the column above the Mercury in the reservoir is always the same, so that though the Mercury runs up a longer length of tube the level of its surface is unchanged.

If the height of the Atmosphere diminishes its weight, and consequently the resultant pressure from it, it will also diminish similarly the height of a

column of Mercury it will balance; therefore, on ascending a mountain, where naturally the height of the Atmosphere above is less, a resultant lower Atmospheric pressure is found.

The next point arising is—" What does the Atmospheric pressure actually amount to ? " Under normal conditions at sea level, the height of the column of Mercury balanced is 30 inches (0·76 m.). A cubic inch of Mercury weighs 3433·5 grains or 0·49 lb. Thus, the weight of a Mercury column of 30 cubic inches pressing on its base of one square inch is equivalent to 0·49 lb. × 30 cub. inches = 14·7 lbs., or in round numbers, 15 lbs. per square inch. Instead of repeating the figure 14·7 lbs. per square inch, the term " atmosphere " is frequently employed to define that pressure. This is the normal pressure of the Atmosphere on each and every square inch of the surface of the Earth and upon all objects on it.

The existence of the internal sustaining pressure can be demonstrated very clearly by a simple every day experiment. Every Fireman knows of the rough and ready method of testing the suction of a Manual Fire Engine, —viz., press the moistened palm of the hand over the suction inlet, whilst a comrade works the levers up and down. If the manual is in good working trim the palm of the hand is apparently violently sucked up the suction pipe, and the skin will afterwards be found to be red with suffused blood, and at times quite painful. What has really happened ? By the pumping action of the manual we have diminished the density or rarified the Air in the suction pipe, thus reducing its elasticity or pressure and leaving the palm of the hand unsupported. Consequently the tissues of the hand with the contained air and blood under full Atmospheric pressure have pushed forward in an attempt to fill the gap and thus restore equilibrium. The reduced Atmospheric pressure between the palm of the hand and the pump constitutes a partial vacuum—that is, a space from which the Air has been approximately exhausted. A perfect vacuum, that is to say Zero pressure, cannot be obtained by mechanical means. The present limitation with the best of modern air pumps is a remaining pressure of about 1/50th of an inch of Mercury column. With ordinary pumps as used for innumerable purposes in every day life, this residual pressure is seldom less than 4 inches of Mercury column. In this country it is customary to measure and speak of the degree of " vacuum " in inches of Mercury ; thus, if in a vertical glass tube arranged with its lower end immersed in a bowl of Mercury, and its upper end connected to the suction of a pump, a column of Mercury rises equal in height to the pressure of the Atmosphere, then the vacuum produced is said to be " perfect." In practice it seldom exceeds 26 inches of Mercury.

Now a vacuum is an unnatural thing, and, if any unseen crack or cranny is overlooked, Air, or some other fluid pressed forward by it, will assuredly rush in, and thus restore equilibrium. It is for this reason that the utmost care should be given to the maintenance in efficient working condition of suction hose and couplings. An old, hard, worn washer, a slack coupling due to a burred thread, a slight pin hole in the hose itself, or even a slack gland or hardened packing, will greatly reduce the capacity of the pump and give a spluttering and inefficient stream of water.

These considerations give the key to the working principle of " Fire Engines " (pumps). If a " perfect " pump could be placed 34 feet above the level of the water, and the suction hose pumped out until a " perfect " vacuum

was obtained, under normal conditions the water driven by the atmospheric pressure would gently rise in it as far as the pump, that is up to the 34 feet level, *but not more,* so that, after all, not even a drop of water could be obtained to extinguish the Fire.

In practice the " perfect " pump and consequently the " perfect " vacuum do not exist, also, from the total pressure of 14·7 lbs. or its equivalent head of 34 feet (exactly 33·88 feet) a portion must be deducted, which is absorbed in pushing the water through the pipe, against what is generally known as the " friction head " or the resistance opposed, the amount of which depends upon the velocity of the water, the number and type of bends, and the degree of roughness of the interior surface of the suction pipe or hose. In good Fire Brigade practice, considering the large volumes of water required by modern appliances, one always aims at as short a suction column as possible, or, better still, water straight from a hydrant, and thus under good pressure right to the pump.

There are continual variations of the Atmospheric pressure, due to fluctuations of temperature and the amount of moisture in suspension, and these are measured by means of instruments known as Barometers, the most simple of which is the tube of Torricelli, when fitted at the upper end with a scale graduated in tenths of an inch, or better still, in millimetres. This is the old and reliable column Barometer of which there are innumerable modifications. The essential points about it are the thorough removal of Air and moisture from the tube, so that there is no counter pressure on the head of the Mercury column ; and a lower reservoir large in comparison to the amount of Mercury drawn from or returned to it by variations, which otherwise would appreciably affect its Mercury level.

The most widely used type of the day is the Aneroid Barometer, or " Barometer without Liquid."

It is constructed of a thin metal cylinder B, from which the Air has been exhausted, counterbalanced by a spring D, so that at normal temperature, and at sea-level, the pressure of the atmosphere and that of the spring are equal. Consequently, any decrease in atmospheric pressure allows the spring to overcome the vacuum of the cylinder, and, conversely, with the slightest increase of pressure, the power of the vacuum overcomes the spring. Attached to the spring is a system of levers J, connected by a fine chain N passing over a central spindle O with the indicating hand F, and by this means, any movement of the vacuum chamber is multiplied, and the slightest variation of the Air pressure is shown by an appreciable movement of the indicator. The divisions on the dial are made to correspond with the inches of the Mercurial Barometer, and all well-made Aneroids are carefully graduated by being placed under the receiver of an Air pump, together with a Standard Instrument, and the divisions marked accordingly. Sometimes

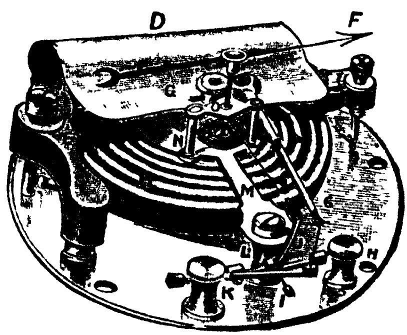


Fig. 5.

the pointer is replaced by a pen, and the scale of a graduated card revolved by clockwork. The instrument then draws a diagram indicating all the variations, and is called a Barograph.

The composition of the Atmosphere is the next point of interest. The lower regions of the Atmosphere of to-day (in the past it was of widely different composition and probably will be again in the distant future) is, normally, a mixture, not a compound, of one volume of Oxygen and four volumes of Nitrogen (O 20·6, N 79·4) with minute proportions of Water Vapour, Carbon Dioxide, Argon, and unimportant traces of the rare gases Neon, Helium, Krypton and Xenon. Ozone, also, is occasionally present.

Oxygen (O) is a colourless, odourless and tasteless gas, slightly heavier than Air (density compared with Air = 1·105). When subjected to the "critical" temperature (temperature above which a gas cannot be liquefied by pressure alone) of − 118° Cent. and 50 atms. pressure, it becomes a pale blue liquid, which if further cooled and exposed to ordinary atmospheric pressure, "boils" at the temperature of − 182° Cent. below the freezing point of water. By application of intense cold produced by the evaporation of liquid Hydrogen, Dewar succeeded in freezing liquid Oxygen to a snow-like pale bluish solid. Oxygen is soluble in water at ordinary temperatures to the extent of 3 to 4 per cent. It is the most active elementary substance known, and in chemical combination with other substances forms about 50 per cent. of the outer crust of the Earth. It is essential to life, for it is that element which, by means of the wonderful process of slow combustion, known as respiration, cleanses the carbon-laden blood, returning it to the system recuperated and fit for further circulation. Oxygen is too active a substance to be breathed alone by Man when in normal health, and tends to produce excessive exhilaration of the heart. Some diluent, or modifying agency, is therefore necessary. The inert gas Nitrogen is provided for this purpose, and not only tempers the too active Oxygen, thus enabling it to be breathed, but also by its presence prevents the too energetic "oxidation," or combination of Oxygen with other substances, which would result in the destruction of all combustible matter on the face of the Earth. Oxygen is the great active agent in Fire, for, with the exception of the case of a limited number of special chemical combinations, without Oxygen the smallest flicker of flame cannot exist. Oxygen is also Nature's great scavenger and disinfector, for by decomposition or slow combustion, it gradually converts rotting organic matter into useful products, principally Carbon Dioxide and Water Vapour, both of which are essential to plant life, and indirectly to animal life.

Ozone (O_3) is an important modification of Oxygen (O_2). The Oxygen molecule consists of two atoms, whereas the Ozone molecule is formed by the union of three atoms. Graphically the Oxygen molecule = ○○, and the Ozone molecule = $\overset{\bigcirc}{\bigcirc\,\bigcirc}$.

This modified molecular structure results principally from the action of electric waves on Oxygen.

Ozone has a distinct, fresh, penetrating odour, not unlike very faint Chlorine. Its presence is often noticeable after thunderstorms, and in the vicinity of static electrical machines in action.

Ozone is an unstable gas of blue colour. At atmospheric pressure and

temperatures below —119° C. it condenses into a deep blue fluid. At the temperature of —12° C. and the pressure of one atmosphere, Water will dissolve up to 50 per cent. of its volume of Ozone.

The oxidising activity of Ozone is much greater than that of its very energetic parent substance Oxygen, and it is, therefore, employed as a bleaching and purifying agent in several industrial processes; notably the sterilisation of Water, for which, on account also of its high solubility, it is eminently suited.

Nitrogen (N) is a colourless, tasteless, odourless gas, slightly lighter than Air (density compared with Air = 0·9714). At the critical temperature of —146° C. and 35 Atmospheres pressure, it forms a colourless liquid, which if further cooled forms a white solid; it boils at —194° C. Nitrogen is soluble in water at ordinary pressures and temperatures to the extent of 1·5 per cent. Under the action of the electric arc, or high tension discharge, Nitrogen burns feebly with Oxygen to form Nitric Oxide, but will not support life or combustion. Unlike Oxygen, Nitrogen is distinguished by its inert qualities, by virtue of which it is slow and reluctant to enter into combination with other substances, although some of its compounds are very active. Carried down by the rain in various chemical compounds, and absorbed also directly and transformed by bacteria, it forms a plant food of immense importance.

Carbon Dioxide (CO_2) is a compound of Oxygen and Carbon, that well-known elementary substance familiar to all in many forms and compounds, such as the diamond, graphite, anthracite, coal, coke, charcoal, wood, etc. It is a colourless, odourless gas, heavier than Air (density compared with Air = 1·529). At the critical temperature of —34-35° C. and 1,095 lbs. (73 atmospheres) pressure, it forms into a colourless liquid, which if allowed to flow into an open receptacle, cools itself by its own evaporation to a white snow-like solid. At atmospheric pressure, liquid Carbon Dioxide "boils" at —78·2° C. It is highly soluble in water under normal pressure and at a temperature of 15° C. up to 100 per cent. An application of this remarkable solubility is ordinary Soda Water, which is merely water saturated with Carbon Dioxide at a pressure of 30 to 35 lbs. Carbon Dioxide is incombustible, extinguishes Fire, renders dangerous mixtures of Air and of combustible gases inexplosive, and will not support life. The principal danger connected with Carbon Dioxide is its great density or heaviness, which causes it when cold to lurk about the floor level. The best known example of this action is perhaps the famous Grotto del Cane (Cave of the Dog) near Naples. In this cavern a stratum of Carbon Dioxide, of volcanic origin, lurks near the floor. A person standing erect is unharmed by it, but if an unfortunate dog enters, it soon falls panting and will die unless speedily removed to the open. Carbon Dioxide is liable to collect in wells, deep cellars, sewers, etc. Its action on the body is to exclude Oxygen, and thus indirectly cause death. Carbon Dioxide is found very generally in smoke, but as long as the smoke is hot and the heavy gases expand with it, it becomes lighter than Air and therefore rises. This inert gas is a product of combustion of carbonaceous matter, the rotting of organic matter or slow combustion processes, and it is expelled from the lungs of animals in the act of expiration. Carbon Dioxide has, in the Fire Service, many applications, which will be dealt with later on, in Chapter XII., under Chemical Fire Extinguishers; but its real sphere of usefulness is to be found in Nature itself. In the first place, in conjunction

with water vapour and the minute particles of dust mechanically suspended in the Air, it limits the irradiation of heat from the Earth into space, thus conserving the warmth of our planet. Its second application is still vaster. It is a means of storing the heat of the Sun. It does this through the agency of that marvellous, and little understood, green colouring matter of vegetation known as Chlorophyll. This substance aided by the rays of the Sun absorbs Carbon Dioxide, decomposes it into plant constituents, and again liberates Oxygen, maintaining the necessary balance of the gases of the Atmosphere.

Carbon Monoxide, see p. 44.

Argon is a colourless, odourless, tasteless gas, heavier than Air (density compared with Air = 1·37). At the critical temperature of —121° C. and 50·6 Atmospheres pressure, it forms into a colourless liquid, which if further cooled to —189·5° C. becomes a colourless solid. Argon is an absolutely inert gas, which, as far as is known, will not enter into combination with any other substance; it is therefore of purely scientific interest.

Of the remaining rare gases, Helium, Neon, Krypton and Xenon, traces only of which exist in the Atmosphere, **Helium** alone is of practical interest. This colourless, odourless, tasteless, incombustible and inert gas, lighter than air, will in the future without doubt replace wholly or in part the combustible gas Hydrogen, at present so widely employed for filling balloons and air ships. Helium has a lifting power 10 per cent. less than Hydrogen, but its diffusion losses (escape through the pores of the envelope) are less, and its incombustibility eliminates the grave risk of fire and explosion, ever present when Hydrogen is employed. Helium was much used in the latter part of the War, 1914-18, for filling the envelopes of air-ships. See Neon (p. 132).

Water Vapour.—It is sufficient to note that water vapour is always present in the Atmosphere, the degree of saturation depending on local conditions of evaporation, and the character of the area of origin and of tracts traversed by the wind ruling at the moment. The warmer the Air, the more water vapour can be carried. For instance, at 32° F. 1 cubic foot can carry 2·1 grains, or at 104° F. 22·1 grains of water vapour, or, which is the same thing, at 0° C. one cubic metre of Air can carry 4·87 grammes of water vapour, whereas at 40° C. it can take up 50·7 grammes. The water vapour in the Air can frequently be watched condensing out as dew on the air-vessels of a steam fire engine chilled by the passage of cold water. Indeed this phenomenon will show an observant Engineer the water level in the vessel, and thus tell him if there is still the necessary air cushion, or if it has been completely absorbed by the water under pressure. This phenomenon is frequently erroneously termed "sweating."

By watching the natural phenomenon going on around, and ascertaining the reason of things, a new interest in life will be gained, and so the unforgettable results of personal observation will be added daily to one's store of knowledge.

Flame, we have seen, is always the result of combustion of gas or vapour. When solid particles—however minute—are not formed in this process, flame is practically non-luminous. A typical example of this is the flame of pure Hydrogen; the flames of candles, lamps, coal gas, acetylene, etc., which are essentially compounds of Hydrogen and Carbon, owe their luminosity to the momentary separation and incandescence of minute particles of Carbon. The presence of this Carbon can be demonstrated by placing any cold (non-

combustible) substance in the flame; lamp-black or soot, that is to say, Carbon, will be immediately deposited on it. If combustion is speeded up by adding the bulk of the necessary Air before the point of ignition, Carbon is not separated and the resultant shorter flame is practically non-luminous. Familiar examples of this action are oil and benzol blow lamps, also the homely incandescent gas burner, properly known as the atmospheric or Bunsen burner, from the great chemist who first made use of it to prevent the deposition of Carbon on his laboratory vessels. The incandescent gas mantle which is formed of a fragile net-work of deposited oxides of rare metals, such as Thorium and Cerium, in its turn clearly proves to us that luminosity is due to the presence of heated solids in the flame. At Fires the causes affecting the luminosity and coloration of flame are the composition of the gases and vapours in combustion, the presence of metals and chemicals, the temperature attained and the amount of Air available.

The air supply, on account of shielding walls and steam clouds, is often insufficient to maintain flame, consequently, large volumes of highly heated combustible gases and vapours pass on unconsumed. Occasionally, in their progress through the burning pile, they find a further supply of air, accompanied by a means of ignition: then explosive combustion results, spreading the flames with lightning rapidity. In other words, flame is a loyal enemy which signals its presence, whereas unconsumed combustible gases and vapours constitute a lurking danger of explosion and ultra rapid fire propagation.

Water.—The second of the original " elements " has always been and still is the most potent ally of the fireman. It is a mobile, apparently colourless fluid, and in one form or another occupies two-thirds of the whole surface of the globe.

All water comes originally from the sea. As a vapour it is constantly given off to, or absorbed from, the Air by all exposed surfaces. The amount of water vapour the air can carry depends, principally, upon its temperature. The higher the temperature the more vapour the air can retain, and *vice versâ*, but it must be remembered that there is still an appreciable amount of moisture or water vapour in air at temperatures as low as —30° C. (54° F. of frost). That is to say, that particles of water, even when in the form of hoar frost, snow and ice, still continue to give off vapour.

A very common example of this effect of temperature on carried vapour is furnished by the human breath on a cold day. This heated mixture of Carbon Dioxide, Nitrogen and residual Oxygen, is expelled from the lungs laden with the original water vapour contained, plus that absorbed from the moist surfaces of the respiratory organs. As soon as this heated, vapour-laden mixture of gases comes in contact with the external air it is chilled, and, as it can no longer retain so much water vapour, the excess condenses out as a visible mist or cloud, which again rapidly disappears by being absorbed in the bulk of the air, which is seldom more than two-thirds saturated with vapour. Under normal conditions of pressure there are four causes which influence the rapidity of the formation of vapour, and of evaporation from a fluid. These are:—

(1) The temperature of the fluid. The higher this is, the greater the rapidity of evaporation. Boiling is the extreme case.

(2) The amount of vapour already existing in the atmosphere.

Occasionally, although it does not actually rain, the cold pavement of the roads becomes wet and sloppy. This simple phenomenon is due to the complete saturation of the air, which consequently cannot under these conditions take up further moisture. Inversely, in some climates the air at times becomes so dry that the finger-nails tend to crack and the skin becomes so harsh and arid that, especially about the fingers, it tends to split and peel. Evaporation is then very rapid.

(3) The rapidity of removal of the air in contact with the fluid. It is well known that everything dries more rapidly in a wind than in still air.

(4) The extent of the surface of evaporation. It is almost self-evident that the larger a surface is, the greater will be the evaporation from it. We have seen that water vapour is nearly always being given off to the air from all exposed wet or damp surfaces. This evaporative action explains the process by which nature maintains an adequate supply of moisture throughout the world.

The heat of the Sun causes invisible vapour to rise into the air from all water surfaces, moist ground, and vegetation. This process is known as evaporation, and by it all salt and other solid matter is left behind, the rising vapour consisting of practically pure water. When this vapour is chilled it becomes visible, and then according to its height above the Earth, it is known as mist or clouds.

These clouds are moved at a greater or less speed from place to place by the air currents. When the moist clouds come into contact with a cold stratum of air, the vapour is further chilled, with the result that moisture is condensed, and, according to the degree of cold, falls in the form of rain, sleet, hail, or snow.

The amount of rain falling in different parts of the world differs enormously. Malden Islands and some other islands in the Pacific and for some distance on each side of the Equator are stated to be practically rainless; while in some parts of India, a country which is subject to the moist winds of the monsoon, a very heavy rainfall is experienced. Some places register an annual rainfall of 250 inches.

Much of the moisture that falls upon the land is absorbed by the soil and vegetation, but in course of time it reappears at a lower level in the form of springs, which in turn join other springs, forming streams and rivers which in due time find their way back into the sea. In the case of rocky ground the rain is at once thrown forward into the streams and is lost, while an absorbent or well wooded soil will act like a sponge and retain the water in the high lands well above the levels of the springs for long periods (see Fig. 6), and thus provide the feed necessary to keep the springs running during the dry months of the year. The condensed moisture, falling in the form of rain, is nearly pure water, and during its course through, or over, the land, and along the rivers, it becomes contaminated with all kinds of animal, vegetable and mineral matter, which it carries to the sea.

Pure water consists of two parts of hydrogen and one of oxygen, and is denoted by the symbol (H_2O). At its greatest density, 39·1° F. (3·94, called 4° C.), it weighs 62·35 lbs. per cubic foot, or one gramme per cubic centimetre.

The density of water is an important factor. Water in cooling contracts until it reaches the temperature 39° F. (4° C.) when all further contraction ceases. This point is called the point of maximum density. When cooled below this temperature **expansion** sets in, which, expansion increases rapidly as the freezing point, 32° F. (0° C.), is approached. Water is therefore heaviest at the temperature of 39° F. (4° C.). Consequently, ice floats upon the less cold water underneath. Water expands about 10 per cent. when converted into ice. The force of this expansion is almost irresistible.

The commonest form by which this pressure is demonstrated is in the bursting of charged water-pipes when exposed to such low temperatures.

It is often loosely stated that these pipes burst during a thaw, whereas the truth is, of course, that the burst takes place during the frost, and does not become apparent, as the fracture is blocked by ice, until the thaw sets in, melting the ice and allowing the water to escape from the fracture.

The fact that the maximum density of water is reached before the freezing point is contrary to the general law of contraction. If it were not so the ice, as soon as it formed, would sink, and in due time the lake or river would become one solid mass of ice.

This floating ice, to a great extent, shelters the water underneath from the frost, and thus the heavier water is kept in a liquid form.

The freezing action of water is most useful to the land in forcing open the soil and allowing the air and moisture to work down.

Water at its maximum density was used by the Scientists who compiled the Metric System to evolve their unit of weight, the Gramme being the weight of one cubic centimetre of water at its greatest density.

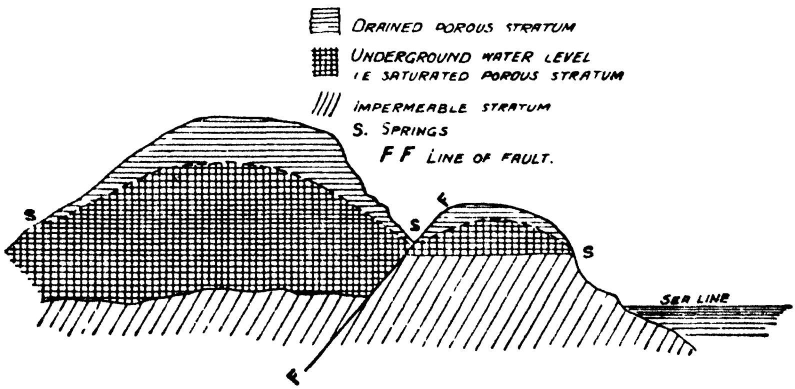


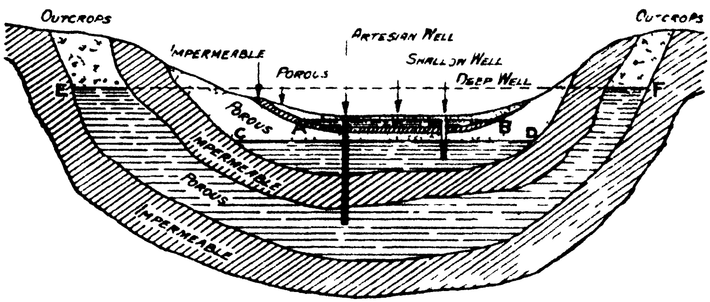
Fig. 6.

Springs.—In its passage through the soil the rain which has already absorbed carbonic acid from the ground air, is capable of dissolving some of the mineral constituents of the rocks over which it passes. It sinks through porous strata until it reaches—as it usually does at a greater or a lesser depth—an impermeable stratum. Here is it upheld, forming an underground reservoir, the natural outlet for which are **springs.** If these are formed in superficial beds of sand or gravel overlying a stratum of clay, they are called "land springs," while "main springs" are the deep-seated outlets of underground reservoirs, issuing from such geological formations as chalk or sandstone.

This underground water line in the land changes its level with the rainfall season of the year, being usually highest about the month of March in Great Britain. The level also varies with the position in reference to the outlet (whether river, springs, or the sea), the curve of the wet soil under the surface becoming steeper as it approaches that outlet (see Fig. 6).

Water from main springs is usually clear and sparkling, wholesome for drinking, but frequently hard.

Wells.—Wells (see Fig. 7) are usually divided into 3 groups, shallow, deep, and artesian, but the last is merely a variety of a deep well. Shallow wells are those which are sunk into superficial beds of sand or other permeable soil overlying an impermeable stratum.



DIAGRAMMATIC REPRESENTATION OF STRATA.
SHOWING SHALLOW, DEEP AND ARTESIAN WELLS.

AB Subterranean water level in surface strata
CD do do do deep do
EF do do do water bearing strata supplying artesian well.

Fig 7.

Deep Wells.—Deep wells are those which are sunk to considerable depths in search of water through regular geological strata such as chalk, oolite and sandstone. Sometimes these are boreholes of only a few inches diameter, just large enough to take the necessary tubing for the lift pump. But often the well is a dug one of considerable diameter, 6 to 10 feet (1·8 to 3 m.), for part of the way, carefully steened throughout, and then a borehole sunk to the required water-bearing stratum. The upper lined portion is then used as an underground reservoir, holding two or three days' supply. Artesian wells are those where, the level of the water in the water-bearing stratum being higher than that of the ground at the mouth of the well, the water rises in the borehole near to, or above, the level of the ground. It has been found in many cases that the driving of horizontal galleries below the water level is more effective in increasing the yield of wells than deepening them, as the area of collection of water is thereby increased and there is a greater likelihood of striking the fissures through which the largest volumes of water are moving.

As mentioned in Chapter XI., the ancient inhabitants of the Island of Andres are stated by Pliny to have used leather pipes or tubes attached to a bell of lead that was sunk to the bottom of the sea to cover a spring of

fresh water. The fresh water rose up the pipe to the surface of the sea and was used for domestic purposes.

At the present day the inhabitants of the islands of Teneriffe rely almost entirely for their water supply upon what rain they can collect and store in tanks. Round the shore line there are a few places where fresh water can be obtained; these are in a pervious strata in the volcanic rocks of which the island is formed. Fig. 8 shows the opening in the stratum of impervious rock which at Bajamar is 12 inches (0·3 m.) thick. The opening is irregular in shape and some 25 inches (0·6 m.) across.

This hole is situated 8 feet (2·4 m.) below ordinary high water mark and 50 feet (15 m.) from the top of the cliff. After the sea has receded the hole has to be baled out three or four times before potable water can be obtained. The fresh water level remains 19 inches (0·6 m.) below the top of the rock and the water 13 inches (0·33 m) deep. This level is about 9 feet (2·7 m) above low water.

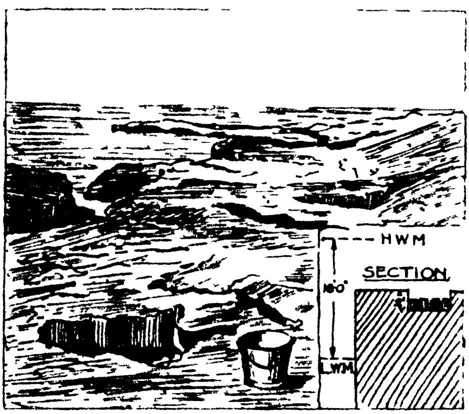


Fig. 8.

The small village of Bajamar obtains all its best water from this hole.

Fresh water is usually divided for consideration into soft and hard waters. The hardness of water is due to the presence of carbonates of lime and magnesium and is designated by so many degrees of hardness, every grain of carbonate or its equivalent in each gallon of water being considered as one degree of hardness.

Sea water is about 2 per cent. heavier than fresh water, and, owing to the salts contained therein, is more effective in extinguishing fire than fresh water.

The fire extinguishing properties of salt water are :—

(1) As the water evaporates the salt cakes on the burning mass and prevents the access of Oxygen.

(2) At high temperatures it gives off the vapour of Sodium Chloride which will not support combustion.

(3) Any Magnesium Chloride or Magnesium Bromide are decomposed by heat, liberating Chlorine and Bromine which will not support combustion.

Water readily absorbs air and other gases under pressure, and parts with them when heated or when the pressure is reduced by pumping. It is for this reason that a suction pipe should never be laid with an upward ∩ bend, as, under the reduced pressure, air in the water will gradually be liberated and form a bubble or air lock at the highest part, and obstruct the passage of the water. Suction pipes should always be laid with a gentle rise from the strainer to the pump.

Water newly thawed from ice or snow, not having had time to absorb any atmospheric air, also produces a more marked effect upon burning material than water that has become aërated.

Every hundred parts of water contain in solution about $2\frac{1}{2}$ parts of gases. An average proportional percentage of such gases is, by volume, nitrogen 66·4; oxygen 31·2; carbon dioxide 2·4; the oxygen being in greater proportion than in air, owing to its greater solubility in water.

Rivers carry the surplus water out to sea. In the case of small rivers like those in Great Britain, the catchment area of which is in a great measure subject to the same general features of climate, the quantity of water is largely regulated by the local rainfall. In wet seasons the rivers overflow and in dry times diminish, and in some cases the flow may even disappear. This does not often happen, because a proportion of the water is derived from springs, which in turn are supplied by the gradual drainage of the (suspended) water retained by the sponge-like soil.

Most of the principles explained in the section on air apply equally to water so far as the pressure of the atmosphere is concerned.

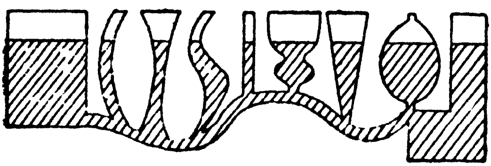


Fig. 9.

Water can be readily poured from one vessel into another, and will adapt itself almost instantaneously to the shape of the vessel into which it is allowed to run. Any change of shape of the vessel (see Fig. 9) causes little resistance, but water offers very great resistance to forces tending to diminish its volume. It is important that Firemen should remember that water is practically incompressible, and consequently, if reciprocating pumps, more especially when fitted with a flywheel, are started with all outlets closed, something is bound to go.

The force by which particles comprising a body are held together is called cohesion and varies in degree to a very large extent in different substances, but in the case of water it is so small that it may for practical purposes be considered not to exist at all. Water will arrange itself in such a way that all particles composing its surface, if connected, will be the same distance from the centre of the earth. In other words, water will find its own level.

The pressure at any point upon the sides of a vessel depends only on the depth—*i.e.*, the head—of the water.

The height of a column of water is sometimes spoken of as the "head" of water, which gives the pressure. Thus we speak of the pressure of the atmosphere, which is 14·7 lbs. (taken as 15 lbs.) to the square inch (one kilogramme weight per square centimetre), as equal to a "head" of water of one "atmosphere" or 34 feet (exactly 33·88) (see p. 25, under Air). Upon the Continent pressures are given in atmospheres, thus, 60 lbs. on the square inch would be stated as 4 atmospheres; 75 lbs. as 5 atmospheres, etc.

If the pressure upon the water at any point is changed, that at all other points is changed also, and, from the fundamental property of a fluid, it follows that the change of pressure at all points is the same.

Consider a vessel filled with water to be fitted with three or more openings of the same area, as shown in Fig. 10, and each opening fitted with a piston. To keep the pistons in their places, force must be applied to each. If an increased external force is applied to one of the pistons, thus driving it inwards, the others will be driven outwards unless such additional force is externally applied to each. Should, however, the pistons differ in area, the force necessary to maintain any piston in position will be found to be proportional to the area of the piston: the ratio of the force to the area over which it is applied is the same for all.

Pascal illustrated the transmissibility of pressure in a fluid by a simple apparatus called a Hydrostatic Bellows (see Fig. 11). A strong bladder,

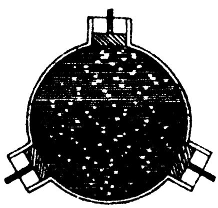


Fig. 10.

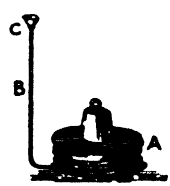


Fig. 11.

such as is used in a football, has attached to it a small tube B, fitted with a funnel C. Lay the bladder upon a table, and on the upper side place a board A with a weight. On pouring water into the funnel the bladder will expand and cause the weight to rise, the amount of such rise depending upon the height that the water in the tube B is above the board A. The upward thrust will depend upon the height of the water in the tube and also upon the area of the water-filled bladder in contact with the board. If the area in contact with the board be large, the upward thrust may be considerable.

From the foregoing it will be understood that if two pump barrels of the same size fitted with pistons, as shown in Fig. 12, are connected by means of a pipe P, any pressure or weight W, which may be put upon the piston in A will transmit a similar pressure to the underside of the piston in B, and lift the weight. Now suppose ten B barrels in place of one were connected by pipes to A, the water from A on being forced down would be transferred into the ten barrels in equal proportions. Therefore, in order to raise each of the B pistons with their weights one inch, it would be necessary to force down piston A 10 inches. The pressure on all 10 will be equal.

By combining the ten barrels into one of ten times the area, as shown in Fig. 13, and joining the two by means of a single pipe, A equalling 1 square inch and B 10 square inches, a pressure of 1 lb. on the piston of A will transmit a pressure of 10 lbs. on the underside of piston B, because the area of B is equal to total areas of the ten barrels mentioned above. The piston A would have to travel ten times the distance of B, that is, 10 inches to lift the piston B 1 inch.

The above is the principle underlying the working of the Bramah Press, and is used in hydraulic cranes, presses, etc. Where water power is required for large installations it is usual to keep a hydraulic pump continually at work lifting a heavily weighted piston or ram, termed a hydraulic accumulator, corresponding with A (Fig. 13), the water being drawn as required through strong pipes from the local accumulator to the hydraulic machinery. The hydraulic accumulator merely acts as a storage vessel for water under pressure and takes up the fluctuations due to the draw off.

Another most important law appertaining to liquids, is that they spread sideways and the unit pressure thus exerted will always be found (at any particular depth) to coincide exactly with that of the downward pressure at any particular depth.

In an open vessel, the unit pressure depends solely on the depth, or dif-

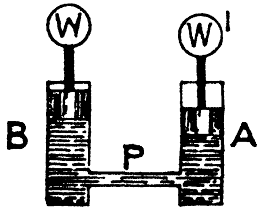


Fig. 12.

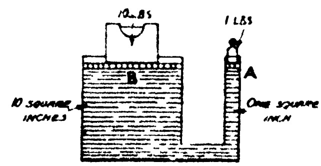


Fig. 13

ference of level between the surface of the vessel or reservoir, and the point down the reservoir at which the pressure is taken.

The different shapes of the vessels, as in Fig. 9, do not alter the pressure in any way, the unit pressure at any point being due only to the difference of level between that point and the uncovered surface of the water in the vessel.

The water supply of a town usually comes from a reservoir at some height above the town, consequently the water in the mains is under pressure. The height to which a jet of water will flow from the nozzle of a branch pipe depends upon the height of the water in the reservoir above that nozzle after taking into account the loss caused by friction in the mains and the air resistance.

Air resistance is dealt with in the chapter on fire streams, but its enormous effect must be thoroughly impressed on the minds of the firemen. An example of enormous air resistance is seen in the famous Staubbach Waterfall on the small river Pletschenbach, near Interlaken in Switzerland. The stream has a considerable fall in its course, with the result that the water attains great speed before reaching the ledge of rock over which it falls for a distance of 984 feet (300 m.). At first it falls quite freely in the form of a solid column of water, but soon it breaks, and about one-third of the way

down is in the form of spray which is further reduced to a fine mist of milk-like appearance until it reaches and deposits itself on the piles of broken stone at the foot of the precipice and, being collected in a deep basin, again flows onward as a rapid stream.

Water flowing through holes in the side of a vessel will do so with a velocity due to the head of water above the outlet; the lower the hole, the more rapid will be the flow (see Fig. 14).

The pressure at any point of a fluid at rest is the same in all directions about the point.

The pressure or thrust on the plane base of a vessel containing fluid does not depend on the shape of the rest of the vessel, but only on the area of the base and on the depth of the liquid. Thus, three vessels, A, B, and C, Fig. 15, have the same area of base and depth of water. The unit and total pressure on the bottom is in each case the same. In the case of C the water also exerts an upward thrust upon the inclined surface which varies according to the depth of water above the point of thrust.

In order to make it clear that water presses equally in all directions, we

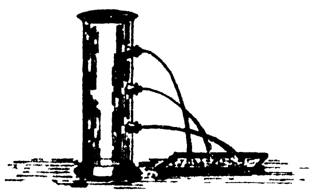


Fig. 14.

A B C

Fig. 15.

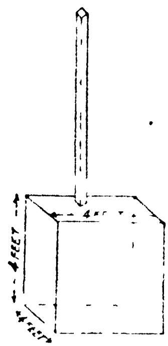


Fig. 16.

will suppose that a tank 4 feet (1·22 m.) square and 4 feet (1·22 m.) deep, closed at the top with the exception of a hole an inch (0·03 m.) in area is filled with water. It would contain $4 \times 4 \times 4 = 64$ cubic feet (1·81 m.^{3}), and, with the weight of water at 62·4 lbs. per cubic foot, would weigh 3,994 lbs. (1,812 kg.), and this would be the pressure on the base of the tank.

To find the pressure on the sides, multiply the weight upon the base (3,994 lbs.) by the number of the sides, and the mean pressure (average)—*i.e.*, half that due to a head of water of 4 feet; or ·87 lb. (0·4 kg.). The total pressure on the sides and bottom will be $\frac{3{,}994 \times 4}{2} = 7{,}988 + 3{,}994 = 11{,}982$ lbs. (5,435 kg.). The opening would prevent any pressure on the top. Now fit an inch (0·03 m.) square pipe, or round pipe of equivalent section, 100 feet = 1,200 inches (30·48 m.) long into the hole in the top of the tank and fill it with water. The amount of water contained in the pipe will be 1,200 cubic inches (0·02 m.^{3}). Taking the weight at ·036 lb. per cubic inch, the weight of water in the pipe will be only 43·4 lbs. (20 kg.), but a large additional

pressure has been produced in the tank. The area of the top, bottom and four sides, six in all, being each 4 feet × 4 feet = 16 feet × 6 = 96 square feet = 13,824 square inches (8·92 m.^{2}). The pressure of water due to the head of 100 feet in the pipe is 43·4 lbs. on the square inch (3 kg. per cm.^{2}), and the resultant pressure on the six surfaces due to the insertion of the pipe with its head of water will be 13,824 × 43·4 lbs. = 599,961 lbs. (272,138 kg.), nearly 268 tons.

Therefore the weight of the water in the 4-foot (1·22 m.) tank would be 1·78 tons, say 1¾ tons, while the pressure in the tank due to the head of water would be 150 times the weight of the water—viz., 268 tons.

If facts like the above were remembered, people would not be surprised when old boilers in the basements of high buildings burst, particularly when the water supply tank is up in the roof. (See p. 48 as to increase due to heating).

Good hose, even when new, cannot withstand the pressure caused by forcing water up to a great height, such as a church tower or high hill.

Consider the pressure upon the bottom length of a line of hose suspended from the Golden Gallery 78 feet (23·77 m.) below the top of the cross of St. Paul's Cathedral. The height of the gallery above the street is 288 feet (88 m.), so that the pressure of water if the hose were simply filled, would be 125 lbs. on the square inch (see p. 91).

To project an inch jet of water from the Gallery over the top of the cross, 366 feet (111·5 m.) above the ground would require, in all, some 200 to 220 lbs. (13·6 to 14·9 atms.) pressure on the square inch to be maintained in the pump at the ground level.

Moral.—When water is required in very high buildings, if possible keep it stored handy with a ready means of increasing pressure. In very high districts where the water supply is poor, underground tanks containing at least one hour's fire supply sufficient for the surrounding fire risks, should be provided (see Fig. 79). For isolated works or mansions a pond may be arranged so as to be both ornamental and useful.

The application of the forces necessary to employ water usefully is further set out in Chapter III.

Fire.*—Science has taught us that matter is indestructible, and that, although our candle may disappear as a candle in performing its useful function of supplying us with a somewhat fitful light, the constituents of which it is composed are not lost, but have merely assumed new and gaseous forms.

Antoine Laurent Lavoisier, born in 1743, when chemical science could hardly be said to exist, devoted his life to researches on the subject of combustion, and gave us the first true explanation of the cause and nature of fire.

Starting with the discovery that a substance burnt in air gave products of combustion heavier than the original body, he gradually arrived at the fact that air is necessary for combustion, and was able with these weapons

* In 1906 the author had the honour of supplying the late Prof. Vivian B. Lewes with pertinent practical questions for his Cantor Lectures on Fire, Fire Risks, and Fire Prevention.

The Royal Society of Arts have kindly allowed extracts from their Journal to be given.

to attack and overthrow the theory of Stahl. Then came the discovery by that triumvirate of genius, Priestley, Lavoisier, and Cavendish, of the composition of air; and that, instead of being an element, as had always been supposed, it contained oxygen and nitrogen. It was the discovery of oxygen by Priestley in 1774 that in reality placed the means of completing his research on combustion in the hands of Lavoisier, who showed by his experiments, the wonderful combustions of phosphorus, sulphur, charcoal, and steel in oxygen.

In all these cases the phenomena observed are dependent upon the formation of combinations of oxygen with the bodies burnt, the phosphorus yielding us phosphorus pentoxide, the charcoal carbon dioxide, the sulphur the gas we know as sulphur dioxide, whilst the steel, the only one of these substances, be it noted, which burns absolutely without flame, yields the solid oxide of iron as the result of the combination. During these conditions energy is developed, and owing to its intensity by concentration into a short space of time, this energy manifests itself as heat and light.

Here, then, is to be found the key to all the actions which we speak of under the general term of "fire," and further experiment soon shows us that in order to start this rapid combination between the substances to be oxidised and the oxygen of the air, it is only necessary to heat the combining bodies to a temperature known as the "ignition point," a temperature which varies very widely with different substances, but which is a constant factor in all bodies of the same composition. Some substances, such as certain organic compounds with zinc, ignite below the ordinary air temperature, and such bodies are called "spontaneously inflammable," whilst others, like phosphorus, have only to be slightly warmed in order to produce the rapid combination known as combustion. Others, again, like coal, have to be heated to a temperature of a little over 932° F. (500° C.) before their ignition point is reached, whilst bodies like steel, having their ignition point above the temperature reached in ordinary combustion, are looked upon, as a rule, as non-combustible.

The spread of ordinary fire and flame is due to the fact that when combustion is started by the ignition point being reached, the combustion raises the temperature generally well above the ignition point of the burning body, so that as one particle burns it ignites the next, and this action continues until the burning body has entirely combined with oxygen, but if the heat generated be insufficient to raise the body to the ignition point, combustion ceases as soon as the source of external heat is withdrawn.

It is an action of this character that safeguards our atmosphere, the main constituents of which consists of 20·9 per cent. of oxygen diluted with 79·1 per cent of nitrogen. If an electric discharge be passed through the atmosphere a flame is seen to burn above the spark, and oxides of nitrogen are produced in abundance, showing that at the temperature of the electric discharge the nitrogen and oxygen are undergoing combustion. The moment, however, that the discharge is stopped the action ceases, as the temperature produced by the combustion itself is so low that it is unable to induce the continuance of the action. Were it not for this, the first flash of lightning, by starting combination between the constituents of the atmosphere, might denude the globe of its aerial envelope.

Although the igniting point of any substance is a fixed and unalterable

temperature, the size of the mass to be ignited plays a very important part, as the smaller the mass the more easy is it to raise it to the ignition point.

For instance, iron ignites at about 2,732° F. (1,500° C.), and gunpowder at a little over 482° F. (250° C.), yet if some alcohol in a dish be ignited and finely divided iron dust be thrown into it, the iron burns brilliantly in the flame, whilst grains of gunpowder may be thrown through the flame without ignition, and will remain unacted upon in the alcohol until it is nearly all burnt away, when the flame, burning down and coming into contact with the grains of gunpowder for some time, heats them to the necessary temperature and so causes ignition. In the same way a very small flame held in contact with a block of wood fails to ignite it, whilst a splint or shaving cut from the block is easily lighted by the same flame.

So far, we may summarise the facts with regard to combustion by saying that combustion is the generation of energy as heat by extremely rapid chemical combination, which is brought about by the ignition point of the substances entering into such combination, being attained.

Although the ignition point marks the temperature at which ordinary combustion gives rise to the phenomena of light and heat, the same chemical action may be proceeding at temperature short of the ignition point, but at so slow a rate that the energy developed is able to spread itself to the surrounding objects and so escape notice.

A tree left to rot upon the ground gradually disappears in the course of years, being mainly oxidised into gaseous products such as carbon dioxide and water vapour, and yet scarcely any evolution of heat is observed, although the same amount of heat is generated as if the tree had been cut into logs and burnt.

If a steel watch-spring with a small piece of ignited German tinder attached to the end of it is plunged into a vessel of oxygen gas, the combustion of the tinder ignites the watch-spring, which burns away in the gas with the greatest brilliancy, and the evolution of heat is sufficient to fuse the metal, the final result being that the watch-spring is converted into a chemical compound of iron and oxygen.

We can judge approximately the amount of heat developed in this experiment by the fact that the steel watch-spring is fused as it burns, which we know requires a temperature of 2,732° F. (1,500° C.). If, however, we took a second watch-spring of the same weight as the first and exposed it to moist air for two or three months, it would also be converted into oxide, but in the slow rusting away of the metal no appreciable heat could be distinguished, it having been dissipated to the earth, the air, and the surrounding objects as rapidly as it was generated. If, however, we could construct a calorimeter sufficiently delicate to measure all the heat evolved during the slow rusting away of the metal, we should find that exactly as much heat had been developed as would have been the case had it been burnt away in pure oxygen. Indeed, the atmospheric rusting of iron may become so rapid as to create a temperature sufficiently high to attract our attention; as, for instance, when a mixture of sawdust and iron filings is swept up from a workshop floor and the heap moistened with water. After a few hours it is found that steam is being evolved, the heat of oxidation having been kept in by the non-conducting sawdust until the temperature had risen to the evaporation point of the water.

The more finely the iron is divided the larger will be the surface which it will present to the oxidising influence of the air. By chemical means we can prepare extremely finely-divided iron in an atmosphere devoid of oxygen, which, on being thrown into the air, rusts so quickly as to become red hot. The slow action taking place below the ignition point is chemically identical with the action taking place during rapid combustion, and only differs from it by being spread through a longer space of time, and is, therefore, called "slow combustion."

Substances subject to the process of slow combustion constitute very serious fire risks, as it is only necessary to collect them in sufficient quantity and under favourable conditions for the generation of heat to begin. If this heat cannot be dispersed as fast as it is generated a general rise of temperature takes place. This in turn increases the rapidity of the chemical action and finally, when the ignition point is reached, results in fire.

Cases of this kind, in which the temperature of ignition is reached by the heat of slow combustion being kept in by non-conducting material, are called "spontaneous combustion," or "spontaneous ignition," see pp. 47-48.

The ordinary phenomena of combustion, as is commonly known, consist of incandescence, flame, and smoke, and, as stated, the prime cause of these three is the rapid evolution of energy developed during the combination of the combustible with the oxygen of the air. If a substance be a solid which is non-volatile at the temperature of combustion, or which is not decomposed by it into gaseous products before burning, incandescence alone is the result of the combustion, whilst all flame is caused by the combustion of gaseous matter.

If bituminous coal or resinous wood be burnt, flame is formed, whilst if coal or charcoal be used as the fuel no flame accompanies the primary combustion, this being due to the fact that in the former case hydrogen and carbon in various forms of combination are driven out from the coal or wood by the temperature generated in the combustion, and being in the form of gaseous or vaporous products, burn with flame. When these hydro-carbons, however, have been got rid of in the gas maker's retort or the charcoal burner's heap, it is the residual carbon alone that burns, and being non-volatile at the temperature employed, no flame results, save under conditions which will be described later.

The smoke which accompanies most ordinary forms of combustion is a product of great complexity, and differs very widely with the nature of the substances being burnt. Practically all forms of fuel, and by far the largest proportion of the substances consumed during a fire, contain carbon and hydrogen as their most important constituents, and with free access of air, the products of combustion consist of water vapour, nitrogen, and the two oxides of carbon, carbon dioxide and carbon monoxide. The proportion of these present depends upon the mass of incandescent carbon, the amount of air which can gain access to it, and the condition of the surface of the fire, so that with a brightly burning mass of timber urged on in its combustion by a brisk wind, and with the surface well alight, practically nothing but carbon dioxide escapes, in company with water vapour and nitrogen, whilst if the interior of the mass be well alight, and air is only slowly passing through it, and the products escaping from the surface at a comparatively

low temperature, then smoke containing a very high percentage of carbon monoxide will be formed.

Of the gaseous products of combustion, steam alone plays an important part in the formation of smoke, whilst the other important constituents are tar vapour, minute particles of unburnt carbon, and ash, drawn upwards by the draught created by the fire.

The smoke, however, from the combustion of a coal fire, or the conflagration of a store containing textile fabrics or much resinous wood, forms a heavy black cloud, the deepening of density and colour being due to the presence in it of minute particles of unconsumed carbon, which have been deposited during secondary chemical actions taking place in the flame of the burning material.

Take, for instance, the case of a building in which a fire is just commencing, the smouldering wood, carpets, etc., not yet in full blaze, give out a whitish smoke of no great density but very choking character, consisting almost entirely of these floating tar vesicles produced by the distillation of compounds of carbon and hydrogen at temperatures of about 1,295° F. (700° C.) to 1,475° F. (800° C.). When, however, the premises are well ablaze, especially if it should happen to be an oil store, then besides the white smoke we get the dense black smoke, due to the presence of large quantities of carbon particles.

The heat of the combustion raises the air around to a very high temperature, and as all gases expand under the influence of heat and become lighter than the surrounding atmosphere, a strong up-current is at once formed, which sucks fresh air into the fire, so aiding its combustion, and at the same time draws up from the fire itself large quantities of particles of ash and still burning material, so that the smoke clouds which roll away from the fire consist of :—(1) Water vapour. (2) Tar vapour. (3) Carbon particles. (4) Particles of ash. (5) The gaseous products of combustion. The variations in the smell and suffocating effect upon firemen are due to the varying properties of the tar vapour distilled off from the substances undergoing combustion.

The amount of carbon in smoke is far smaller than is generally supposed, even when it is given off by bituminous coal under the imperfect conditions of combustion existing in an ordinary fireplace.

The subject of smoke from the point of view of danger to life deserves far more attention than it has ever received, as more lives have been lost from suffocation than from actual burning.

All know how different is the smell of smoke arising from different substances, and that when present in not too large quantities the nature of the smoke can be detected. For instance, tobacco smoke, the smoke from burning soot, from rags, from timber, or from animal matter, all differ in smell so widely and are so distinctive that very little experience enables an observer to form a conclusion as to what kind of material is burning. As the smoke grows denser the nose becomes less able to differentiate the smell. The irritating effect of the smoke on the eyes, nose, and respiratory organs increases, until a certain density is reached, when the smoke-laden atmosphere becomes irrespirable and consciousness ceases.

This difference in smell is almost entirely due to the liquid envelopes of the tiny vesicles that constitute the principal portion of the smoke, the liquid

being composed of the products of the action of the heat upon the burning substance, which are mostly of the same character as the products that would have been obtained if the substance had been subjected to destructive distillation in a retort. Coal-smoke has the mawkish gassy smell of the hydrocarbons developed in its distillation, tempered by the sulphur compounds emitted at the same time; burning wood, on the other hand, gives smoke acrid and pungent to the eyes and nose, owing to pyroligneous or acetic acid, the vapours of wood—wood-naphtha, naphtha, acetone, and similar bodies.

Smoke is nearly always worst in the early stages of a fire, and although in the day time it is often the best fire alarm possible, at night it is a serious danger to the sleeping inmates, and hampers the rescue work of the firemen. Being formed during combustion, the gases within the floating vesicles and the other products are expanded by the heat which formed them, and are lighter than the surrounding air, and rise, so that even in a room full of dense smoke breathing is possible close to the floor, whilst anything which will filter off the tar vesicles and dust leaves the air in a condition fit to breathe for a certain time.

The construction of a satisfactory smoke and dust respirator for use by firemen under conditions where the smoke is so thick as to seriously impede their labours, is by no means an easy problem, and of the hundreds of such appliances that have been suggested and made, very few even approach efficiency. Indeed, the lessons of the late War have proved that respirators of any kind are at the most palliatives and the only real remedy is to provide a supply of oxygen, see Chapter XII.

During the early stages of a conflagration, when there is more smoke than fire, a good smoke respirator or filter of simple construction would afford some help, as the poisonous products of incomplete combustion are absent, but when a fire has been in progress for some time and there is a considerable mass of incandescent carbonaceous matter at the seat of the mischief, a large proportion of the product of incomplete combustion, carbon monoxide, begins to make its appearance with the smoke, nitrogen, steam, and carbon dioxide. This introduces a new and serious source of danger to the workers owing to its intensely poisonous character.

The increase in quantity of this gas with increase in the mass of burning material is due to several factors:—

1. When the mass of incandescent matter is large the amount of air is rarely sufficient to complete the combustion, and carbon monoxide is produced.
2. With increase of temperature the proportion of monoxide to dioxide increases with great rapidity.
3. The playing of water on to the incandescent carbonaceous mass and the action of the steam generated on the glowing carbon yield carbon monoxide.

It might be imagined that as carbon monoxide ignites at about 1,295° F. (700° C.) and burns readily in air, forming the comparatively harmless carbon dioxide, there would be but little chance of any escaping unburnt with the products of combustion, but dilution plays an important part in preventing

the combustion of such gases, and air may contain from 16 to 18 per cent. of oxygen still left in, and yet extinguish the flame of carbon monoxide if there be any considerable percentage of carbon dioxide present in it.

It is generally stated that air which extinguishes a flame is irrespirable and will not support life, but it has been shown clearly that if the oxygen in the air be reduced to about 17 per cent. and the carbon dioxide increased to between 3 and 4 per cent., either by respiration or by combustion, although a candle placed in this air will be at once extinguished, the mixture may be breathed by a healthy man for a very considerable period without any noticeable effect being produced.

Carbon dioxide is not a poison, but acts by keeping the oxygen of the air away from the lungs, and in small quantities by interfering with the diffusion processes which, in the lungs, enable the blood to discharge the carbon dioxide formed in the body, and to re-oxygenate itself from the inhaled air. When 6 per cent. of carbon dioxide is present in the air, men inhaling it begin to pant, and show signs of distress, which becomes severe with 10 per cent., whilst 15 per cent. soon leads to unconsciousness.

With carbon monoxide, however, a distinct toxic action is set up with the presence of even small traces in the air inhaled. The gas forms a definite compound with the hæmoglobin of the blood, and so prevents it from carrying out its normal functions; 0·1 per cent. of carbon monoxide in the air will, after half an hour's breathing the atmosphere, produce inability to walk, whilst 1 per cent. will produce unconsciousness in a couple of minutes, followed by death if the man "gassed" is not quickly removed to an uncontaminated atmosphere. Should a man be overcome, artificial respiration and the inhalation of pure oxygen is the only treatment to employ.

Rapid combustion or fire is induced when the ignition point of a substance is reached, but in studying the causes of fire, it is soon discovered that fire is by no means limited to those cases in which the combustion is caused by the direct application of flame, or other source of heat, many secondary actions tending to bring a mass of material accidentally to its ignition point.

On taking the causes of fire as revealed by the statistics of any large town, one generally finds that matches in one way or another are a most prolific cause, whilst defective vents and flues, or fireplaces, owing to the overheating of beams and woodwork near them, also mount up to a very large total, the other cases being due to a number of causes, amongst which the spontaneous ignition of goods in bulk plays an important part.

The means by which fuel is raised to the ignition point, and by which it kindles those sources of artificial light that depend for their action upon combustion, must be, and always have been, amongst the most prolific causes of accidental fire, and taking the statistics of the most important towns in Great Britain, it is not surprising to find that a large proportion of the fires are due directly, or indirectly, to matches.

The match is now so much a part of civilisation and life, that it is impossible to recognise what life would be without it.

The discovery which really made the possibility of the phosphorus match was that, if a warm solution of glue were taken at 112° F. (44° C.), and both the phosphorus and oxidising material were stirred in it, the phosphorus melted and became separated into excessively small particles by the stirring

whilst the oxidising material dissolved. On tipping the match-heads with such a mixture, when dry, the particles of phosphorus were entirely surrounded and protected by a thin film of the glue, and it was not until friction upon a roughened surface in the striking of the match broke down the glue partitions that the phosphorus and oxidising material could act upon each other. The friction at the same time supplied the necessary heat to ignite the phosphorus, which then burnt partly at the expense of the oxygen of the air and partly at the expense of the oxidising material added to the match-head mixture.

The number of accidents arising from matches soon began to attract attention, and attempts were made to lessen these dangers. In 1855, Lundström, in Sweden, manufactured safety matches by separating the phosphorus and the oxidising material, and making the match tip of very much the same character as the old "Lucifer" head, whilst the phosphorus was put in the striking composition on the side of the box, the substance being used in its allotropic modification, the not easily inflammable red phosphorus. In some Continental works the use of phosphorus in any form has been abandoned, although it is very difficult to get anything like the same certainty of ignition without its aid.

In considering the fire risks due to matches we shall find that they really fall under five distinct heads :—(1) The dangers during manufacture ; (2) The dangers during storage and carriage ; (3) The flying off of an ignited head, or breaking off the unignited head during the striking ; (4) The improper use of matches, such as their use as playthings by children ; (5) The after results, such as matches thrown down whilst alight, the glowing of the stick after use, and the falling off of the red-hot head, etc., this latter class of risk being undoubtedly the most prolific in causing accidental fires.

These last troubles, however, can easily and readily be got over by soaking the wood, of which the matches are made, in solutions of such salts as ammonium phosphate, boracic acid, or other well-known "antipyrenes."

With the exception of those dangers due to absolutely inexcusable carelessness, the danger of the match can easily be overcome by using nothing but safety matches. When using these matches it must be remembered that the box itself must be kept from contact with oxidising materials like potassium chlorate, as a good many accidents have happened from contact between a potassium chlorate throat lozenge and a safety match box in the same pocket.

This arises from the fact that in the head of the safety-match there is a mixture of chlorate of potassium with sulphide of antimony and glue, whilst the striking mixture on the box consists of a mixture of red amorphous phosphorus, sulphide of antimony, and glue. When the match is lightly rubbed on the box the glue walls are broken down, and the phosphorus and oxidising chlorate come in contact, giving a sufficiently high temperature in their combination to cause the sulphide of antimony in the match-head to burn at the expense of the oxygen of the chlorate. When, however, the chlorate is used as a lozenge or tablet it is generally mixed with sugar, and the heat of the combination between the chlorate and the phosphorus on the box causes the sugar, which is a compound rich in carbon and hydrogen, to burn at the expense of the oxygen of the chlorate.

It is oxygen that supports the ordinary forms of combustion; such bodies as the chlorate or nitrate of potassium contain 600 times their own

volume of oxygen, and as air is roughly one-fifth oxygen, a cubic inch of these salts is equal, in its oxidising power, to 3,000 cubic inches of air.

Having reached the ignition point of the wooden splint of the match by three stages, the temperatures representing the ignition point of the head, the intermediate coating, and the wood, the combustion of such material as coal can then be obtained by having recourse to the ease of ignition which is given by fine division of a mass. We know by experience that if we apply a match direct to a stick of wood, although the temperature of the flame is far above the ignition point of the wood the mass of the stick so distributes the heat that the ignition point is not reached, and this is the case even to a greater degree with a lump of coal, whilst a piece of paper is rapidly and quickly ignited by means of the match flame.

Now paper and wood both have as their chief constituents the compound of carbon, hydrogen, and oxygen, known as cellulose, this material in the case of paper being diluted with various substances added as loading, and to give surface, whilst in the wood it contains bodies that were originally present in the sap, and a certain amount of moisture. The igniting point of both is, however, nearly the same, the paper having an ignition point of 876° F. (470° C.), whilst the bundle of wood placed near the side of the stove to dry overnight ignites at from 932-968° F. (500-520° C.).* When the match is applied to the paper, the paper rapidly ignites, burning for a sufficient length of time to reach the ignition point of the wood, and this again burning for a considerable time heats the coal up until sufficient of the mass has been raised to the ignition point to ensure its combustion.

Next to matches as a cause of accidental fire comes the firing of woodwork by faults in flues or overheating in the vicinity of the fireplace. One would imagine that such a thing as building a beam into a chimney, or laying a joist close under the hearth of a firegrate would be so manifest a danger as to ensure its never occurring, but such criminal carelessness is by no means so uncommon as one might imagine, and in such cases it is only a question of time and chance for a fire to be caused.

A beam, the end of which impinges on the interior of a flue, may be so far above the grate that for years no trouble arises, but the hot upcurrent of gases in the chimney will gradually dry, and carbonise the wood, whilst any collection of soot in the chimney catching fire will start a smouldering combustion in the beam that may go on for a considerable time before it gets sufficient air to cause it to break into active combustion.

A more usual source of danger is to be found in the perishing of the mortar used in building the flue, and so leaving gaps in the brickwork behind which the woodwork is situated. Mortar practically consists of a mixture of slaked lime and sharp sand, and when brickwork has been laid with this, the first hardening of the mortar is dependent upon the slaked lime absorbing carbon dioxide from the air, which converts it into carbonate and causes it to harden, whilst after the lapse of many years a further action takes place by the silica of the sand acting on the calcium carbonate to form a silicate of great hardness and strength. With modern buildings, however, the first action is the only one that has taken place.

The brickwork in the interior of a flue is often very roughly laid, being out of sight, and instead of the work being made of bricks laid true and

* These figures appear somewhat high.

nearly touching, broken bricks, and a considerable quantity of mortar are used. After this has set, the action of heat upon it is again to burn the calcium carbonate back to lime, so causing the crumbling down of the mortar, and should a joist have been built in close to the casing of the flue, hot gases will find their way through the perished mortar to it, and gradually bring about carbonisation of the wood, and thus cause its ignition.

All heating dangers are largely increased, and indeed chiefly exist from the fact that lightly-charred wood becomes almost pyrophoric in its character, and can readily be set on fire at temperatures considerably below those needed to start the combustion of either uncharred wood or charcoal. The changes taking place in wood under the influence of long continued heating are of a complex and interesting character.

Wood consists mainly of a definite chemical compound called cellulose, a body formed from carbon, hydrogen, and oxygen, and besides cellulose, wood contains the constituents of the sap and a varying quantity of water. The amount of water present depends upon the season of the year and the portion of the tree from which it is taken, whilst the percentage is as a rule greater in soft than in hard woods, the following table giving an idea of the quantity present in various kinds of wood :—

Beech,	18·6 per cent.
Oak,	34·7 „
Common Fir,	32·7 „
Alder,	41·6 „
Elm,	44·5 „
Poplar,	50·6 „

When wood is placed under cover and exposed to the air for about a year the moisture is reduced to about 20 per cent., and the remaining moisture can be got rid of by subjecting the wood to the action of heat, the last portions requiring a temperature sufficient to char the wood. If, however, the wood be heated somewhat below this point the greater part of the moisture is removed, but on again allowing the wood to cool to atmospheric temperature, and exposing it to the air, the hygroscopic nature of the wood gradually attracts moisture until the percentage reached is about 20, at which point a sort of equilibrium is established between the moisture in the air and the wood.

When wood is exposed to the long continued action of heat it undergoes progressive changes nearly akin to those which have taken place during the conversion of vegetation into coal. Up to 212° F. (100° C.) practically only moisture is expelled from the wood, and at a few degrees above this point not only water but volatile hydrocarbons are slowly driven out, whilst at 302° F. (150° C.) oxides of carbon, together with more hydrocarbons, are disengaged, and slightly above this temperature the wood commences to assume a scorched appearance, and to turn brown. At about 482° F. (250° C.) wood is converted into a soft brownish form of charcoal which is its most dangerous form, being highly pyrophoric and self-igniting at comparatively low temperatures. At 572° F. (300° C.) the carbon begins to assume the appearance of soft black charcoal, getting harder and more metallic in its properties as the temperature increases.

The chemical changes which are taking place in the charcoal at these varying temperatures are strictly shown by the following table :—

Temperature.	Carbon.	Hydrogen.	Oxygen.	Ash.
520° F. = 270° C.	71·0	4·60	23·00	1·40
685° F. = 363° C.	80·1	3·71	14·55	1·64
890° F. = 476° C.	85·8	3·13	9·47	1·60
966° F. = 519° C.	86·2	3·11	9·11	1·58

It is seen that as soon as 520° F. (270° C.) is reached the action consists in a gradual increase in the percentage of carbon, owing to the elimination of hydrogen and oxygen, and it is clearly due, therefore, to compounds still containing these three elements in comparatively large proportions that the pyrophoric carbon owes its dangerous character. If the contact of wood with a heated surface be continued for a sufficiently long period of time, a temperature of a few degrees only above the boiling point of water is enough to produce a semi-carbonised film on the wood, which will start smouldering at a very low temperature, the heat rising from an oil lamp or gas flame some distance away being sufficient to start smouldering combustion. Indeed, the temperature of a steam pipe has been found sufficient to cause ignition, this being due probably to the long continued heat generating certain hydrocarbons of low ignition point, which remain occluded in the pores of the semi-charred wood, and are there brought into close contact with the occluded oxygen.

It must be remembered that when using steam heating, although the boiling point of water at ordinary atmospheric pressure is only 212° F. (100° C.) yet the boiling point rapidly increases with increase of pressure, as is shown by the following table :—

Pressure in atmospheres.	Lbs. on the square inch.	Boiling Point.	
		°F.	°C.
1	14·7	212	100
1·5	22·1	234	112·2
2	29·4	250	121·4
3	44·1	275	135·1
4	58·8	294	145·4
5	73·5	308	153·1
6	88·2	320	160·2
7	102·9	330	166·5
8	117·6	342	172·1
10	147·0	359	181·6
12	176·5	374	190·0
14	205·8	387	197·2
16	235·2	399	203·6
18	264·6	409	209·4
20	294·0	419	214·7
25	367·5	440	226·3
30	441·0	457	236·2
35	514·5	473	244·8
40	588·0	487	252·5
45	661·5	511	265·9

So that in lofty buildings heated either by water or steam it is quite possible to obtain temperatures which will dangerously char wood in contact with the pipes, whilst with air as the heating medium it is by no means uncommon to find a dull red heat in the pipes and flues near the furnace. Nor does the danger cease when care is taken that the pipes or flues used for these methods of heating are kept several inches away from any woodwork, as in inaccessible places the accumulation of dust on the pipes often gives rise to trouble.

When a hot-water or steam-pipe is laid alongside a wall, it will be noticed that where a flange or other projection of a pipe touches the wall there is a brown stain produced on the wall surface streaming upwards from the point of contact and becoming less the further it gets from the place where it starts. Experiment shows that this is due to dust settling on the pipe becoming carbonised and ascending with the hot-air current produced by the pipe; this current comes in contact with the surface of the wall, and the hot gases rapidly diffusing through, the charred particles are filtered off, remain on the surface of the wall, and give the stain. When, however, the accumulation of dust is large, the carbonised mass, being in a very loose state of aggregation and made up of very minute particles, will often start glowing with a very slight increase of temperature above the ordinary temperature of the pipe.

The fire risks due to lighting are of a most varied character, even daylight itself not being free from danger, hundreds of fires having been caused by the accidental focussing of the sun's rays by means of a full water-bottle, irregularities in the window pane or other cause, which has led to the concentration of the sun's rays upon some inflammable substance. The dangers from artificial illumination are set out in Chapter IV.

We have seen that to create fire we must reach the ignition point of a combustible body in the presence of oxygen, the latter gas being present either in the air or in some oxidising compound, whilst to carry on the fire the supply of oxygen must be continued, and the temperature maintained above the ignition point, a failure in either of these requirements causing extinction of the fire.

With the exception of such fires as are caused by petrol collodion, and a few other bodies of the same class which burn with such deadly rapidity as almost to defy checking, most fires have small beginnings, and are so easily dealt with in the earlier stages that unless they are given time to gather force their extinction is readily compassed, and it is this latter factor which is the most valuable asset in what is known as "fire prevention," but which is really "fire restriction."

We must have fire, but we must have it under control; we must limit its actions to our requirements, and we can only do this by, as far as possible, removing anything upon which it can feed from contact with it and, above all, preventing it from spreading from the area in which we are utilising it, or if by ill chance it should so stray, then by having the means of dealing with it before it gets out of control.

There is nothing to which the old adage, "Prevention is better than cure," applies more aptly than to fire, and with the object of prevention in view, enormous sums have been spent in the erection of what are called with grim humour "fireproof buildings," the absolute inutility and absurdity of which title has been fully demonstrated by some of the largest fires of modern times.

This disastrous state of things has been brought about by a complete misconception of what was really required to check the spread of fire, and by a be-muddled confusion of the terms "fireproof" and "fire-resisting."

No building material that could be practically employed is "fireproof," *i.e.*, has the power of resisting the action of heat without undergoing a physical or chemical change. Granite and sandstone crack and fly under its influence; limestone, even at such moderate temperatures as 1,470° F. (800° C.) decomposes and yields lime; bricks fuse, and so do iron and steel; and the result is that at the fierce heat engendered by a big warehouse fire, the most refractory materials prove themselves of but little resistant value, whilst the methods of construction employed make them an active danger.

CHAPTER II.

LAW—FORMATION AND MANAGEMENT OF BRIGADES—INQUESTS—EVIDENCE.

Law as Affecting the Practice of Fire Fighting.—From time immemorial measures of various kinds have been enacted to reduce the frequency and disastrous effects of fires, as well as to ensure the provision of means to enable outbreaks to be suppressed. These laws, especially those up to the time of the Great Fire of London, have ceased to have any effect. They would obviously be totally inapplicable to the conditions of the present day. They did, however, possess one virtue which might very easily and with considerable profit be perpetuated in our later enactments. It is that they are all characterised by a directness of aim and purpose; and it would be commendable if some of our present-day laws were thus framed. However, though these laws are now no more than historic and picturesque examples of a bygone age, they reflect the state of society of those old times, and we are enabled to trace—though faintly—the changing characters of our buildings.

It is regarded as something noteworthy to listen to the curfew (couvre feu) bell (see p. 3), and, viewed as it were from the distance of nine centuries, it awakens in the mind a picture of the social conditions in the early days of the English nation.

In London a law was enacted in the reign of Richard I. compelling the erection of party walls 16 ft. high and 3 ft. thick between neighbours for the prevention and spread of fire.

At other times also measures and orders were made for the supply of men, tools, and water, and for the hanging out of a lighted lantern, or for the provision of pits for water; but all these measures were superseded by those enactments which followed the Great Fire of London in the year 1666.

All writers on this subject agree with very little modification that the Great Fire of London marks the separation of two important periods in the development of the Fire Service. The fire was an altogether unexpected event. It was both disastrous and beneficial. It is true that it almost completely destroyed London as a great city, but it wiped away disease ridden areas, and acted as a potent cleansing agent. It dislocated trade, and destroyed much wealth, but it urged men to discover better means of preventing a recurrence of such catastrophe. It changed men's outlook and gave a great impetus to inventive genius, which has not yet ceased to improve the means of combating fires. But while the great fire was the cause and origin of the present day fire brigade service, it was also a connecting link between the early inventions of fire appliances and those of the present day. Fire insurance also was brought more prominently into notice. The Great Fire, which was referred to as a National Disaster at the time, awoke men's minds

to the sense of their danger and risk. And while one section of the community strove to improve the means to conquer and subdue fire, another and more nervous formed companies to recoup themselves for any loss they might sustain from this cause. Fire brigades were regarded with some amount of suspicion, and the public preferred strong fire insurance companies to strong fire brigades. Fire brigades were in fact looked upon as an executive branch of fire insurance.

The first recorded modern Act of Parliament is 6th Anne, Cap. 58. It set forth that many fires have occurred in London, Westminster, etc., which could have been extinguished before the impoverishing and utter ruin of many of Her Majesty's subjects, if sufficient quantity of water had been provided in the pipes lying in the streets, and if party walls of brick had been built between house and house from the foundation to the top of the roof, etc., etc. This has since been completely repealed.

The next was passed in 1774 and was known as 4 Geo. III., Cap. 78, but as this merely enabled parishes to keep a fire engine, but provided no means for its maintenance, it was almost useless.

This was followed by the first effective measure, viz.: - the Lighting and Watching Act, 1833. (3 and 4 Wm. IV., Cap. 90, Sec. 44). This was an "adoptive or permissive Act" and empowered inspectors appointed under the Act to keep and maintain a fire engine and also to call upon the Overseers for payment of the cost. These in turn were to levy a rate for this purpose upon buildings and land in proportion of 3 : 1.

The Clause reads :—

> "That it shall be lawful for the said inspectors from time to time to provide and keep up fire engines, with pipes and other utensils proper for the same, for the use of the Parish adopting the provision of this Act, and to provide a proper place or places for keeping the same and to place such engines under the care of some proper person or persons, and to make him or them such allowance for his or their trouble as may be thought reasonable. And the expenses attending the providing and keeping of such engines shall be paid out of the money authorised to be received by the Inspectors under the provision of this Act."

In 1840 the Chimney Sweepers Act was passed, principally with the object of preventing the common custom of sending small boys up chimneys for the purpose of clearing them of soot, several cases having occurred in which boys were killed. The practice almost immediately stopped. (The size of all flues was determined to be not less than 14 inches (0·36 m.) by 9 inches (0·23 m.). A large portion of the Act has from time to time been repealed.

Nothing of note was enacted during the next few years, till the Town Police Clauses Act of 1847 was passed 10 and 11 Vic., Cap. 89, Secs. 30-33. It seems as if a multitude of reforms were aimed at in this Act, for :—

> Section 30 enacts that: "Every person who wilfully sets or causes to be set on fire any chimney within the limits of the Special Act shall be liable to a penalty not exceeding £5, provided always that nothing herein contained shall exempt the person so setting or causing to be set on fire any chimney from liability to be indicted for felony."
>
> Section 31 that: "If any chimney accidentally catch or be set on fire within the said limits, the person occupying or using the premises in which such chimney is situate shall be liable to a penalty not exceeding 10/-, provided also that such forfeiture shall not be incurred if such person prove to the satisfaction of the justice before whom the case is heard that such fire was in no wise owing to omission, neglect or carelessness of himself or servant."

Section 32 : " The Commissioners may purchase or provide such engines for extinguishing fire, and such water buckets, pipes or other appurtenances for such engines, and such fire escapes and other implements for safety or use in case of fire, and may purchase, keep or hire such horses for drawing such engines as they think fit, and may build, provide or hire places for keeping such engines with their appurtenances, and may employ a proper number of persons to act as firemen and may make such rules for their regulation as they think proper and give such firemen and other persons such salaries and such rewards for their exertions in cases of fire, as they think fit."

Section 33 : "The Commissioners may send such engines with their appurtenances and the said firemen beyond the limits of the Special Act, for extinguishing fire in the neighbourhood of the said limits, and the owner of the lands and buildings where such fire shall have happened shall in such case defray the actual expense which may be thereby incurred, and shall also pay to the Commissioners a reasonable charge for the use of such engines with their appurtenances and for the attendance of such firemen : and in case of any difference between the Commissioners and the owner of the said lands or buildings, the amount of the said expenses and charge as well as the propriety of sending the said engines and firemen as aforesaid for extinguishing such fire (if the propriety thereof be disputed), shall be determined by two justices whose decision shall be final : and the amount of the said expenses and charge shall be recovered by the Commissioners as damages."

This Act only applies to such towns or districts in England or Ireland as were comprised in any " Special Act " of Parliament passed after 22nd July, 1847, and which declared the Act should be incorporated : but in some rural districts the powers of the Act have been put in force by orders of the Local Government Board.

The same year (1847) saw another Act bearing on the fire service, called the Waterworks Clauses Act 1847, Sec. 38, reads :—" The undertakers, at the request of the towns commissioners shall fix proper fireplugs in the main and other pipes belonging to them at such convenient distances, not being more than the prescribed distance, or if no distance be prescribed, not more than 100 yards from each other, and at such places as may be most proper and convenient for the supply of water for extinguishing any fire which may break out within the limits of the Special Act : and in case of any difference of opinion as to the proper position or number of such fireplugs, it shall be settled " in a similar way as the differences arising from the Town Police Clauses Act 1847—*i.e.*, In England, by two justices. This Act only applies to Waterworks authorised by Acts of Parliament passed since 23rd April, 1847, which incorporate the above provision.

The next important Act was the Poor Law Amendment Act, 1867, Sec. 29, which made it possible, where there was no Town Council, local board, or other competent authority, to put into force means for fire protection similar in character to Sec. 32 of the Town Police Clauses Act, 1847. Action could be taken by the Overseers on demand of the Vestry, and expenses defrayed out of the poor rate. The only notable feature is, that for the purposes of raising the necessary funds, land, except agricultural land, is rated at its full rateable value.

No other measure was passed which affected fire brigades until 1875. In that year the Public Health Act—that great boon to local authorities—was passed. Certain sections slightly modify previous enactments, but a novel feature occurs in Section 285, which enables two or more authorities to combine for the purpose of erecting and maintaining any works that may be for the benefit of their respective districts or any part thereof, including the provision of fire appliances ; and Section 233 enables local authorities with the

sanction of the Local Government Board to borrow for the purpose of defraying any costs, charges, and expenses incurred or to be incurred by them in the provision of fire appliances.

The Police Act, 1893, merely settles the position in law of a police constable who may, in the execution of his duty, act as a fireman, or assist at a fire. It also enables the Police to act as firemen, and the Watch Committee to make all the usual arrangements usually needed in Brigades ; to settle pay, allowances, pensions, etc. The Secretary of State is also empowered to effect such alterations as shall bring existing arrangements into conformity with the Act, by the adjustment, repealing or modifying of provisions in local acts, or to unite any existing fire brigade pension fund with the police pension fund.

The Local Government Act, 1894, made extensive alterations in the previous practice. Borrowing powers are conferred upon Parish Councils for building purposes and permanent work under the Adoptive Acts, and County Councils or Parish Councils are enabled to apply to the Local Government Board for issue of an order to confer upon Rural District Councils the powers of Urban District Councils, and joint action is permitted between two or more parish—or district—councils.

The False Alarm of Fire Act, 1895, inflicts a penalty up to £20 on any one convicted of giving a false alarm in whatever manner it is given, be it by telephone, telegraph, or a verbal message. In London the £20 penalty was inflicted under the London County Council (General Powers) Act, 1903, but under the London County Council (General Powers) Act, 1909, the penalty has been raised to £25.

The Parish Fire Engines Act, 1898, extends powers of parish Councils under the Acts of 1833 and 1867 by enabling them to enter into agreement with, and to use fire appliances in, extra-parochial places, and specifies that where a fire engine is sent beyond the limits of a borough in pursuance of an agreement, the owner of the property on fire shall not be liable for an expense under the Town Police Clauses Act, 1847, as such extra-parochial places are then considered within the limits of the area protected by the fire brigade.

PUBLIC HEALTH ACTS AMENDMENT ACT, 1907, Ss. 87, 88, 89.

87. Any police constable acting under the orders of his superior officer, and any member of the fire brigade of the local authority being on duty, and any officer of the local authority, may enter, and if necessary, break into any building in the district being, or reasonably supposed to be, on fire, or any building or land adjoining or near thereto, without the consent of the owner or occupier thereof respectively, and may do all such acts and things as they may deem necessary for extinguishing fire in any such building, or for protecting the same, or rescuing any person or property therein from fire.

88. The officer in charge of the police at any fire in the district shall have power to stop or regulate the traffic in any street whenever, in his opinion, it is necessary or desirable to stop or regulate such traffic for the purpose of extinguishing the fire, or for the safety or protection of life or property, and any person who wilfully disobeys any order given by such officer in pursuance of this section shall be liable to a penalty not exceeding five pounds.

89. The captain or superintendent of the fire brigade of the local authority, or other officer of such fire brigade for the time being in charge of the engine or other apparatus for extinguishing fires, attending at any fire within the district, shall, from the time of his arrival, and during his presence thereat, have the sole charge and control of all operations for the putting out of such fire, whether by the fire brigade of the local authority or any other fire brigade ; including the fixing of the position of fire engines and apparatus, the attaching of hose to any water pipes or water supply, and the selection of the parts of the building on fire, or of adjoining buildings, against which the water is to be directed.

In Scotland Fire Brigades are maintained under Burgh Police (Scotland) Act, 1892 (55/6 Vic., Cap. 55).

In Ireland the Towns Improvements (Ireland) Act, 1854, 17 and 18 Vic., Cap. 103, empowers Commissioners to provide engines.

This completes the catalogue of Public General Acts concerning the formation and management of Fire Brigades generally, but in many of the large towns of the United Kingdom special Acts have been obtained principally for the purpose of securing payment for the services of the fire brigade at a fire.

The reader cannot, however, fail to be struck by the extraordinary range of Acts of Parliament over which the law relating to Fire Brigades is spread. The fact that the laws fall under such separate provisions as Lighting and Watching, Police, Public Health and Local Government makes the work of presenting a clear statement extremely complicated. And strange as it may seem, it is only through the Acts bearing on the Police that the Government have any control; and even then it only applies to the personnel of the Police brigades.

The law needs consolidating so as to apply equally to all Brigades, whether volunteers or working under Municipal or other Councils.

Beyond the Acts under which fire brigades may be organised and worked, there are many points under the common Law which are of intense interest, and, judging by the many questions which are brought forward in the Courts of Law, it may not be inappropriate to add a few words on them.

These points usually deal with such debatable subjects as outlined in the following.

(1) Excessive charges for attendance at fires.

(2) The non-publication of scales of charges in the case of Volunteer brigades.

(3) The demand for compensation for the loss of water taken from a private source.

(4) The attendance of a brigade at a fire upon premises, the owner of which, or his agent, had not summoned it.

With regard to the last point, the view generally held by Magistrates is that, provided a brigade is a *bona fide* organisation, and its charges reasonable, it is rendering a useful service, and judgment should be given in its favour. An important point to note, however, is that volunteer brigades are not able to sue in a corporate capacity, nor can they be proceeded against as a corporation, but only as individuals.

Brigades generally have no right of claim or action against an Insurance Company interested in a property damaged by fire. The owner is the person liable. Certain towns, however, having obtained special Acts of Parliament, have the right to charge for the services of their brigades within their rateable areas.

The practice of the different brigades is not uniform and as has been mentioned, the whole situation needs careful revision, so that uniformity may be established.

Since writing the above the author has seen the "Red Book" No. 233,

published by the British Fire Prevention Committee. This is an excellent treatise in so far as it applies to existing legislation, but the suggestions as to the administration of the Fire Brigade Services raise questions that would require much thought and care before an opinion could be expressed that they could be adopted with advantage.

The facilities the fireman has to judge of the origin of fires and to detect criminal action or intent are undeniably unique. He is invariably among the first on the scene of an outbreak, and he it is who must search out the fire and extinguish it. By practice and experience, therefore, he becomes almost instinctively a judge, and his conclusions may justly furnish good grounds upon which to base further inquiries. There is hardly any point involving safeguards, which might arise at an inquest, upon which a fireman could not give illuminating information from actual observations and from constantly studying the behaviour of fires in similar circumstances.

The fireman who has the experience and evidence adduced thereby could do much to unravel the mysteries surrounding many serious conflagrations. Experience has been the fireman's instructor. It is information that has never been written in books, and theory is often discounted before his very eyes. He is always ready to learn, and, as a practical student, the fireman has paid for his tuition by heavy sacrifices at the point of duty. Knowledge and yet more knowledge is the aim of every zealous fireman, and indeed ill-equipped would he be if he were not armed with all the information necessary to enable him to judge of the small margin which separates in law accident from design, and negligence from culpability.

In these respects the law covers a very extensive field. It ranges from chimney fires to the misdescription of fabrics and from the conveyance and storage of petroleum, celluloid, and explosives to the protection of children.

It is to be regretted that these Acts have not been codified and therefore it is necessary for the Fireman to obtain each separate Act.

The regulations respecting the storage and handling of Petroleum, Celluloid, Explosives, etc., are dealt with in Chapter IV., and those regarding buildings in Chapter XVIII., and the others referred to are set out below

Since 1840 changes have taken place in the construction of flues, many modern ones having fireclay tubes. The chimney-sweeps of the present day often do their work in a perfunctory manner, with the result that chimney fires are prevalent.

The Burgh Police (Scotland) Act, 1892, authorises the burgh prosecutor to take evidence of any parties he may consider able to give information as to how fires occurred. Refusal to be examined may entail a fine of £10.

By the London County Council General Powers Act, 1900, a sum can be demanded if the chimney of any house or other building within the County of London shall be on fire, the occupier of such house or building being liable on the demand of the Council, made through their clerk or solicitor, to pay to the council a sum not exceeding 20 shillings towards the cost of the Metropolitan Fire Brigade. And if any sum so demanded by the Council be not paid within seven days it shall be lawful for a Petty Sessional Court, on complaint by the Council, to make an order on the occupier to pay to the Council the sum demanded or any less sum fixed by the Court.

Provided that if the fire arose through the neglect or wilful default of any person other than the occupier, the occupier may recover from such person

summarily as a civil debt the whole or any part of the sum he may have paid under this section.

The provision of Sec. 128 of the Public Health London Act, 1891, shall apply to the service of demands under this section.

Children Act, 1908.—There are two sections bearing upon injury or loss of life by fire in this Act. It is essential the fireman should be acquainted with them.

Section 15 concerns the exposing of children to risk of burning:—

If any person over the age of sixteen years of age who has the custody, charge, or care of any child under the age of seven years allows that child to be in any room containing an open fire grate not sufficiently protected to guard against the risk of the child being burnt or scalded, without taking reasonable precautions against that risk, and by reason thereof the child is killed or suffers serious injury, he shall on summary conviction be liable to a fine not exceeding ten pounds.

Provided that this section shall not, nor shall any proceedings taken thereunder, affect any liability of any person to be proceeded against by indictment for any indictable offence.

Section 121 concerns the safety of children at entertainments:—

(1) Where an entertainment for children or any entertainment at which the majority of the persons attending are children is provided, and the number of children who attend the entertainment exceeds one hundred, and access to any part of the building in which children are accommodated is by stairs, it shall be the duty of the person who provides the entertainment to station and keep stationed wherever necessary a sufficient number of adult attendants, properly instructed as to their duties, to prevent more children or other persons being admitted to any such part of the building than that part can properly accommodate and to control the movement of the children and other persons admitted to any such part whilst entering and leaving and to take all other reasonable precautions for the safety of the children.

(2) Where the occupier of a building permits, for hire or reward, the building to be used for the purpose of an entertainment, he shall take all reasonable steps to secure the observance of the provisions of this section.

(3) If any person, on whom any obligation is imposed by this section, fails to fulfil that obligation, he shall be liable on summary conviction, to a fine not exceeding, in the case of a first offence, fifty pounds, and in the case of a second or subsequent offence, one hundred pounds, and also, if the building in which the entertainment is given is licensed under any of the enactments relating to the licensing of theatres and of houses and other places of music or dancing, the licence shall be liable to be revoked by the authority by which the licence was granted.

(4) A constable may enter any building in which he has reason to believe that such an entertainment as aforesaid is being, or is about to be, provided, with a view to seeing whether the provisions of this section are carried into effect.

(5) It shall be the duty of the council of the county or county borough in which a building in which any contravention of the provisions of this section is alleged to have taken place to institute proceedings under this section if the building is a building licensed by the Lord Chamberlain, or is licensed by the council of the county or county borough under the enactments relating to the licensing of theatres or of houses and other places for music or dancing, and in any other case it shall be the duty of the police authority to institute such proceedings.

(6) This section shall not apply to any entertainment given in a private dwelling house.

Fabrics (Misdescription) Act, 1913.—This Act was rendered necessary by the many disasters which had attended the indiscriminate use of flannelette.

1. It shall not be lawful for any person to sell, or expose or have in his possession for sale, any textile fabric either in the piece, or made up into garments, or in any other form, to which is attributed expressly or inferentially

the quality of non-inflammability, or safety from fire, or any degree of such quality of non-inflammability or safety from fire—

(1) by wording or marking, descriptive or otherwise—
(a) upon the material; or
(b) upon the wrapper or band; or
(c) contained in any letterpress or writing referring to the material; or

(2) by verbal representation at the time of sale; unless such textile fabric conforms to such standard of non-inflammability as may be prescribed by regulations to be made by the Secretary of State, and, if any person sells, or has in his possession, textile fabric in contravention to a fine not exceeding, in the case of a first offence, ten pounds, or, in the case of a second or subsequent offence, fifty pounds.

The regulations made in pursuance of the above section were issued on January 20, 1914.

(1) A textile fabric shall be deemed to conform to the standard of non-inflammability, if, when tested in accordance with the prescribed method of testing, it is not set alight, or, if set alight, burns with a flame or with a flame which does not spread but converges and dies out.

(2) The prescribed method of testing shall be as follows:—

A sample of the fabric measuring not less than one square yard shall be taken, and, after it has been four times in succession thoroughly washed with soap and water, dried and ironed, shall be suspended vertically without folds or creases and so that the lower edge shall not be a selvedge or a folded edge. The flame of a wax taper not less than $\frac{1}{8}$ inch or more than $\frac{3}{16}$ inch in thickness shall then be brought in contact with the fabric at its lower edge, and shall be kept in contact for not less than twelve or more than fifteen seconds.

Under the London County Council (Celluloid, etc.) Act, 1915, adequate means of escape must be provided from buildings in which celluloid is stored.

Since November, 1921, the storage and manipulation of celluloid in factories has been subject to the regulations made under Section 79 of the Factory and Workshop Act, 1901. These regulations are enforced by H.M. Inspector of Factories.

Fire Inquests.—The work of constantly dealing with fires becomes as absorbing as it is important owing to the many opportunities which it affords for an intimate acquaintance with the life of the nation. For the moment it is not easy to instance better facilities for seeing things as they are, in their reality, than are at the hand of the fireman. He is called to the small smouldering basket of linen ignited by a spark from the kitchen fire or to the factory well alight and stocked full with goods. He is summoned to outbreaks in hotels full of visitors, and effects rescues in the teeth of the flames, and he finds also the charred remains of the babe in the cot burned to death whilst its mother is away at work. There is both courage and sympathy mingled in the work, and the seamy side of life is as familiar to him as the gilded halls of the well-to-do.

The enthusiasm of the fireman is perhaps more keenly sensitive to the sudden calls for the work of extinction than of prevention, and he ponders more on both of these than on direct and positive checks to the occurrence of fire by the suppression of crime. He might rightly argue that such a duty is the work of the Police. How far crime enters into the origin of fires and accounts for loss of life, probably there is no one better able to judge than the practical fireman.

No amount of inspection, fireproofing, and employment of the least combustible of substances in building will remove the danger of the fire raiser from the community. And it is beyond the authorised scope of the fire brigade officer to do more than extinguish the fire, and ascertain the cause.

Attempts have been made on several occasions to set up a means of enquiry and investigation, but with very little result.

From the earliest times, before the Norman Conquest, Coroners had exercised their powers of inquiry into felonies under the Common Law of England. These felonies included that of " burning houses," and it was usual for the Coroner, Sheriffs and Jury to hold court and enquire into the origin of any fires, whether attended with fatal or non-fatal results. For fully three centuries they exercised this function, but later owing to the curtailment of the Coroners powers of jurisdiction, the holding of these enquiries was dispensed with except of course where the fire was attended with loss of life. There does not appear to be any specific reason why such an obviously beneficial measure should have been allowed to drop into desuetude, but so it remained for over six centuries.

It was due to the action of Mr. Serjeant Payne, Coroner for the City of London and Southwark, that the ancient jurisdiction was revived. Following a non-fatal fire at a warehouse in Aldermanbury in the occupancy of Messrs. Bradbury, Greatorex & Beale, a jury was sworn and an inquest held on 21st August, 1845, in the Board Room of Cripplegate Ward Parochial School, Philip Lane, London. The question as to " how and by what means the warehouse has been burned " was considered and the jury returned a verdict that the fire was the result of an accident. On that occasion Mr. James Braidwood was a witness, and he pointed out the need for more vigilance on the part of the District Surveyor of the regulations of the Building Act and instanced several warehouses in which the cubic capacity allowed had been exceeded, and the liability to the rapid spread of fire correspondingly increased owing to the absence of doors and dividing walls and partitions.

Mr. Serjeant Payne's action was unchallenged, and he continued to hold inquests into non-fatal fires up to 1853, when he discontinued holding them owing to the fact that the Court of Common Council of the City of London did not consider they had sufficient legal warrant.

In 1860 at the instance of the Chief Constable of Manchester, Mr. Coroner Herford held an inquest into the cause of a non-fatal fire. The owner objected that the Coroner had no power to hold the inquest. The inquiry was adjourned and the owner obtained a rule in the Queen's Bench prohibiting it being held.

Since that time until 1888 no inquests were held on non-fatal fires.

In 1882 Mr. W. J. Payne (son of Mr. Serjeant Payne), the Coroner for London and Southwark revived the question of an official enquiry into the origin of all fires. He drew up a letter to the Home Office and attached a specimen draft of the Bill. This Correspondence was published by the Metropolitan Board of Works to whom it was forwarded by the Home Office and they coupled with it a critical letter by Captain Shaw.

Captain Shaw opposed the introduction of fire inquests as he considered the results would not warrant the expense which he computed would even moderately cost £50 per inquest.

However, following an unsuccessful attempt in 1885 by the Metropolitan Board of Works to obtain an act to appoint a special commissioner to inquire

into the causes of fires in the Metropolis, the Corporation of the City of London ultimately introduced a private bill in the House of Commons in 1888 called the City of London (Fire Inquests) Bill. This became law and revived and strengthened the old powers of coroners, but only so far as the City of London was concerned. The question of its possible extension to the whole Metropolis or even to the whole country, though recognised as undoubtedly possessing the essence of a great reform, was deferred to a later occasion.

The successors of the Metropolitan Board of Works, the London County Council, revived the matter in 1906 and 1910. On the latter date a Government Departmental Committee was appointed to enquire into the law generally relating to coroners, and reported under Section III. Jurisdiction, Fire Inquests :—

"Under the City of London Inquests Act, 1888 (51 and 52 Vict. ch. xxxviii)—a private act—inquests are held in the City of London to inquire into fires occurring within its precincts, if attended by loss or injury, even if no loss of life has occurred. The coroner **may** hold such an inquest in any case reported to him by the Commissioner of the City Police or the Chief Officer of the London Fire Brigade, and **must** hold an inquest if so directed by the Lord Mayor, the Lord Chief Justice, or a Secretary of State. If the jury find that the fire was wilfully and unlawfully caused by any known person or persons, they may find a verdict of arson against him or them, and that verdict has the force and effect of an indictment. Apart from this special Act, a coroner has no jurisdiction to hold an inquest or inquiry in case of a fire, however disastrous, unless the fire causes the death of some person (R. *v.* Herford, 3 E. and E., 115), when the circumstances of the fire can of course be investigated at the inquest.

"We have come to the conclusion that the system of fire inquests established by the Act of 1888 has worked well in the City of London, and that the benefit of this system ought to be extended to the country at large. The operation of the Act is both preventive and remedial. The fact that a public inquiry may be held has had a deterrent effect on incendiarism, and, if an incendiary fire takes place, an inquest provides additional machinery for detecting and punishing the crime. The police may suspect arson in certain cases, but may not have sufficient evidence on which to found a charge of arson against a specific individual. They have no power to obtain further evidence by summoning witnesses and examining them on oath. They must be satisfied with such statements as the persons they interrogate choose to give. The City Coroner, on the other hand, by holding an inquest, can bring before him any person who may throw light on the circumstances of a fire, and examine him on oath, and in this way can properly obtain material information, which would not be admissible in evidence where a specific individual was charged with arson before a magistrate. As regards accidental fires, the knowledge that an inquest may be held tends to keep property owners up to the mark in the matter of fire-prevention, fire-extinction, and life-saving appliances, while the holding of an inquest directs attention to these matters, and the evidence often leads the jury to make, by means of riders to their verdicts, useful suggestions as to means to be taken to prevent fires in future. The advantage of an inquest in the case of accidental fires applies particularly to factories, institutions, and other places where large numbers of persons are

collected together. A further advantage of fire inquests would be the improvement of fire brigades. The men would be stimulated to increased exertions, and the attention of local authorities would be called to the need for maintaining their fire brigades in a state of efficiency."

The London County Council in considering the Committee's recommendations stated that they reported on this subject (adoption of the City of London Fire Inquests Act) on 16th Oct., 1906, that while it had no objection to the proposal that inquiries should be held into the cause of all serious fires that might occur throughout the County of London, the Council was of the opinion that it was undesirable that such inquiries should be held in the manner prescribed by the City of London Fire Inquests Act, 1888. It was further stated that if the principle of holding inquiries into the causes of serious fires is adopted, such inquiries should be held only upon the direction either of a Secretary of State or the local authority; and further, that a special department should be charged with the duty of holding the inquiries as in the case of boiler explosions and railway and tramway accidents.

It seems, therefore, that while the extension of inquiry into non-fatal fires is one to which no one has raised any great objection (but on the contrary would rather welcome), the institution of this really practical reform is to be delayed for the inscrutable reason that the Board of Trade and not the Home Office or the Coroner should be the department to exercise authority or jurisdiction. Why Coroners who undoubtedly possessed the ancient jurisdiction, and have both tradition and experience to guide them in the conduct of inquiries, and who furthermore have the power still to conduct inquiries into fatal fires, and have the authority to commit persons for trial, should not be considered capable, with the assistance of Assessors similar to Medical Experts, of administering the law as efficiently in the case of non-fatal fires, needs further elucidation.

Records show that since the City of London has had such inquiry the number of fires returned as of unknown origin has steadily declined, and it is not improbable that an extension of this system throughout the country would do much to put a stop to incendiarism.

The experience of America affords a good object lesson. The New York Fire Commissioner, Mr. Jos. Johnson, states in his report to the Mayor of New York City on Dec. 31, 1912, that the Crime of Arson is rampant in the City, and he makes a widespread appeal to the public. The Commissioner declares that one-quarter of the fire losses of the City of New York, or an annual destruction of not less than $4,000,000, is involved.

"Despite all efforts of conscientious public officials, the strenuous activities of our Fire Marshals, and the detection and prosecution of numerous incendiaries, suspicious fires, particularly among certain well defined trades, are on the increase."

The Fire Marshal (U.S.A.) is a specially appointed officer, and he attends fires and is empowered to examine on oath and if necessary to prosecute offenders.

Here then are two parallel cases which produce opposite results. Fires have noticeably decreased in the City of London while in New York they have increased, notwithstanding that in both places facilities exist for bringing miscreants to justice. Of course, there is no doubt that in both countries arson and incendiarism occur, and it is more than likely that the fire raiser

would choose the ground for operations where his objects would be better served. Inasmuch as New York finds incendiarism increasing there is some real object why this nefarious business can there be made profitable. No incendiary, unless insane, be he ever so foolish, fires for mere enjoyment. Pecuniary gain is at the root, and the channels through which this can flow are to be found mainly in the methods of Insurance.

The recognised practice in America in 1912 was for insurance policies to be issued without the slightest enquiry, and often these policies were effected at sums out of all proportions to the actual value of the risk. The Fire Commissioner mentioned that 135 different policies for $59,500 were issued on property worth only $3·96. Little wonder, therefore, the evil grew. Incendiarism and Arson in America bear a direct ratio to Insurance. The weaker the insurance methods the greater the Incendiarism, etc., and fire raising, as the Commissioner states, becomes a " fine art."

With this evidence we must feel thankful that in this country Insurance business at least is worked on different lines and companies do not invite claims by an unrestricted issue of policies at amounts bearing no relation to the value of the property insured. In all but the simplest cases, inspection and inquiry are made before a proposal is accepted. On the other hand, in our satisfaction at the comparative small amount of arson and incendiarism we must not be deluded into thinking the origin of fires requires no " watching brief." Indeed, having in mind the many food fires which occurred in different parts of this country soon after the signing of the Armistice, decisions should bear the other way.

The question of official investigation into the causes of fires has arisen on many occasions, and in 1884 it was stated " the fact is that investigations cost money and that heavily taxed communities are unwilling to increase their expenses." " As it is, almost everything is left to chance. No public official has the right even to investigate beyond a certain point, and doubtless many a criminal escapes." This was written before the Corporation of the City of London obtained the Act of 1888, but these remarks seem to impel one to the conclusion that enquiry should be made into all fires not only in the City of London which is one square mile out of the 120 of the Metropolis, but also in the latter which should be dealt with as a whole, and in the country in general.

The question of cost is almost negligible. The average cost to the City of London is about £5 per enquiry. There seems no valid reason why fire inquests should cost more than, or even as much as, inquests for other purposes. The machinery exists and it would but mean the revival of the coroners ancient jurisdiction to set the whole machine in motion. Therefore the holding of inquests would not mean any appreciable addition to the expenses of local administration.

The benefits to be derived from the revival of the ancient office exercised throughout the Kingdom would undoubtedly be found in the direction of the further prevention of crime; the improvement in provincial building laws; and the reduction of insurance premiums, besides acting as a real stimulant to the maintenance of high efficiency in the work of fire fighting; while risks incidental to the more hazardous trades would be brought to light and dealt with in accordance with the necessity of the case for the safety of life and property.

Evidence.—It has been remarked that fire fighting and fire prevention, with all the multifarious issues which are bound up in their successful application, involve a knowledge not only of all the sciences, but almost an encyclopædic store of information as to what is more commonly spoken of as "commercial processes."

It would come, therefore, as no surprise to the fireman to learn that in any development, by the adoption of a systematic enquiry into the causes of all outbreaks of fire, he should be prepared to add to his already crowded stock of information the elementary principles of the law of evidence.

Enquiries into the origin of fires would be shorn of much of their real value if they did not include the evidence of the principal agent in fire extinction, and the value of his evidence would be more useful if it was given in accordance with certain simple rules.

To begin with, the value of evidence in a Police Court or Coroner's Court, or, in fact, before any judicial body, depends almost entirely upon the way in which the evidence is given by the witness.

Evidence easily falls into two main classes:—

1. Circumstantial evidence.
2. Real evidence.

Circumstantial evidence does not deal with actual facts to be proved, but of certain circumstances from which inferences can be drawn, of course with much less certainty than in Real evidence.

Real evidence or direct testimony is what should be aimed at in all cases, but as in that of murder, or a fierce fire, circumstantial evidence may be the only means whereby guilt may be connected with an accused person.

Cases occur where false evidence has been blazoned out with all the impertinence and sangfroid of an adept in the art of pleading, while again many a man's testimony has been weakened by the manner in which it has been rendered. A hesitating or stammering manner has a great tendency to unsettle the faith of a jury.

The necessary or sterling qualities required in giving evidence are accurately described as involving "the truth and nothing but the truth." Evidence must be direct, obtained first hand, not through another medium, be it the press or another person. Where a fire is likely to be the subject of an enquiry it is very desirable that the witness should not talk about the matter to the public and much less to the gentlemen of the press.

Conversely it is advisable for an important witness not to read comments upon incidents likely to come before the court.

Evidence should contain all essential facts—nothing omitted or added. Imagination should not be allowed to colour any statement, for evidence should aim at establishing justice between the one side and the other. If these points are followed it will be clear that a fire officer cannot be a partisan.

After a witness has been examined in chief by the party calling him, the opposing side "cross-examine." Leading questions—*i.e.*, those questions indicating the kind of answer desired—are only permitted in cross-examination, not in the examination in chief. Cross-examination, therefore, is not usually found particularly agreeable to witnesses or their temper. Difficulties are not minimised, however, if the witness gives any indication of wavering in his belief in the accuracy of his own statement, and such a wavering may

unfortunately easily arise if a witness loses his temper. It soon underrates the value of the witness' evidence and is invariably taken by the opposite side to be the weak spot in the testimony, and the opposing party will immediately endeavour to undermine its stability.

A great assistance to memory and an invaluable aid in fixing definite dates, times, and localities will be found in written notes. They should be supplemented by sketches, however rough, further amplified by exact measurements. In fact, nothing should be left to chance or the memory. These rough notes can always be copied out, but the originals must be kept, as possibly they may be called for to prove that the actual facts as seen by the witness have not been misstated. Nothing is more irritating to a judge or presiding official endeavouring to reconstruct in his mind appearances of places which a witness is describing, than indefinite data—drawings or sketches afford an easier method of explanation. Vague language again should be avoided, as it only involves a waste of time. For instance, in describing any discoloration found on the floor near where a body was lying, should not be described as " blood " stains until it has been analysed and proved to be blood stains. The mere associations of circumstances would not justify a witness in concluding the stains were of blood. The fact must be ascertained beyond a doubt by medical assistance. Again, it would be wrong to describe a portion of a material as belonging to a damaged garment merely because the texture and colour agreed with a similar material. The material found should be carefully described both as to size, shape, colour, and kind of material. It is for others to say whether it was the part missing from some other garment. Evidence must be exact and not expressions of opinion. Again, in order to locate the original seat of a fire, care should be taken to notice which side of a package, piece of furniture or building, has been most subjected to heat, remembering always that fireplaces, open doors, lift wells, or windows tend to draw a fire towards them. Where it has been possible to make plans to support evidence, they must be so explicit that no doubt could arise in the minds of the assessors as to what the plans were intended to explain. They need not be works of art. It is an old saying that the colouring of plans for a Court of Law should be so thick that it could be felt with a stick.

One imagines that in any regular system of fire inquests where firemen's evidence would probably be required to determine responsibility for the occurrence, firemen would find it essential and necessary to note with greater care than has hitherto been the practice, where the outbreak originated, and to pay particular attention to any facts that would help to discriminate between accident and design, but this is not often done.

There is no law which will define the difference between them. It is a matter differing largely in degree and intention, and it is, therefore, of the utmost importance that careful evidence should be produced on these points.

No one can so carefully arrange matters that mishaps will never occur, and in the causes of fire it is strange what simple things conduce to serious results. However, it is well known that all fires are not the result of accident, and in a careful investigation it is only the trained eye that will perceive the oftentimes small but distinguishing factor.

Where sufficient evidence could be obtained as to criminal intention in fire raising, the issue would be plain. On many occasions insurance companies have taken action, but more, probably for the reason of safeguarding their

funds than from any mere desire to act as public benefactors. It is the many cases where, especially in big fires, there is "a clean burn out" that evidence of the fireman should prove the most useful. It must be remembered that Arson is a most serious offence, and to secure a conviction for this crime the most definite and conclusive evidence is required, which usually has to be confirmed by a second person, but failing such confirmation by direct evidence the testimony must be supported by very convincing circumstantial corroboration.

The above may be considered a guide as to the manner in which evidence is usually required in an ordinary Court of Law, but in cases of Coroners Enquiries evidence other than direct evidence is frequently admitted, and the Coroner is at liberty to take into account and to receive evidence obtained in an indirect manner—*i.e.*, hearsay evidence.

In this connection a photographic outfit would be found a useful addition to the equipment of any fire brigade, especially in the larger cities. From the time of the arrival of the appliance to the finish, in fact throughout the whole development of a conflagration the photographer will be acting as the recorder of events. In Hamburg it was the custom for a photographer to be notified of every fire so that he should record its progress during the fire brigade operations, and the writer personally has known several important instances where photography has cleared up many disputed points, concerning the length of ladders, and whether there were two or three at the front or the back of a building at such and such a time. Such photographic records of details of a fire are invaluable from the prevention point of view, by showing the action of fire upon the various parts of the structure.

Should Cinematography be employed, as was so successfully used during the war by aviators to record the destruction of an adversary, the whole behaviour of a fire could very easily be reproduced before any judicial body of men as the strongest evidence obtainable in settling the often vexed questions involved in charges of delay, and further it would be the greatest aid to the imagination in the education of younger men in the service.

CHAPTER III.

WATER SUPPLY, HYDRANTS, ETC.

Water Supply.—The water supply to large towns has always been considered and rightly so, a matter of great importance, and claims the exclusive attention of one section of Civil Engineering. It will only be touched upon so far as concerns the subject of this work.

In the case of scattered populations it is possible for the individual wants of the inhabitants to be supplied by the rivers, streams, springs, canals, ponds and shallow wells near which habitations are usually erected. (Also see p. 298).

When a number of people congregate in one place and erect a number of buildings upon a limited area, forming villages and towns, the probability of there being a sufficient natural supply of water within the bounds of the town is small, and this supply may soon be contaminated by sewage and manure from neighbouring industrial and farm buildings.

In very early times it was found that an ample supply of pure water was one of the first requirements of a large community. The value of conserving the rainfalls by storage in underground tanks for use during the dry season was (and is) so great as to be a case of life or death to the inhabitants of hot countries. The records of Babylon, and other ancient cities, also the aqueducts near Rome, remain to remind us of the skill and diligence of those early citizens in providing the necessary quantity of water for domestic, irrigation and other purposes. During the middle ages the supply of water seems to have been sadly neglected in Europe, and no attempt seems to have been made to keep in repair the splendid works of earlier times; hence only the ruins of many of these wonderful works of engineering skill now remain.

The town of Dieppe, France, is an early example of what a municipality could do, even in 1530. Their "Fontainier," or water superintendent, constructed a tunnel through the chalk hill which divides the town from a good supply in the valley of the adjoining watershed, and by means of two earthenware pipes 7 inches (·178 m.) in diameter, and 3¾ miles (6 kilometers) in length, provided an abundant supply until the population increased when the town became popular in 1882. It is a matter of interest to know that the water took 15 days to travel the 3¾ miles (6 kilometres), but the time was reduced by the year 1800 to 24 hours.

The present water supply of London, according to John Aubrey, the antiquary, was projected by a Mr. Inglebert who conceived the scheme of bringing water from Ware to London; but as he was a poor man, the work was financed by Hugh Middleton, citizen and goldsmith (afterwards knighted), who undertook the work and was granted a Power of Attorney to carry out the undertaking in 1606 under the Act (3rd James, 1, Cap. 1, 1605). This supply, under the name of the "New River," was opened on Michaelmas Day,

1613, Sir Hugh Middleton obtaining the credit and sharing the pecuniary gain with the King and other so-called "Adventurers." In 1691 the York Building Water Works Company was started to supply Westminster. In 1720 a Mr. Gulston was making £1,300 a year by supplying Southwark with water. Other water works were then commenced, the Chelsea in 1722, the Lambeth

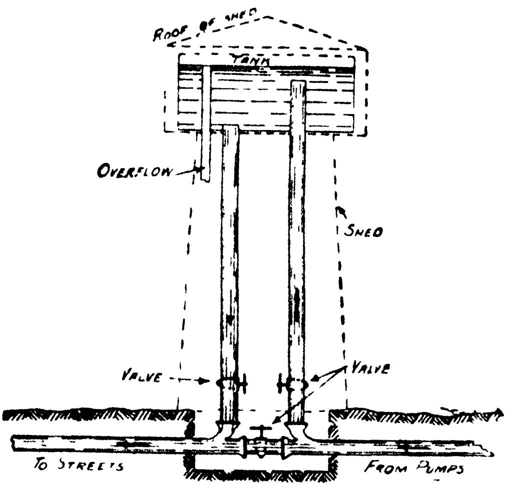


Fig. 17

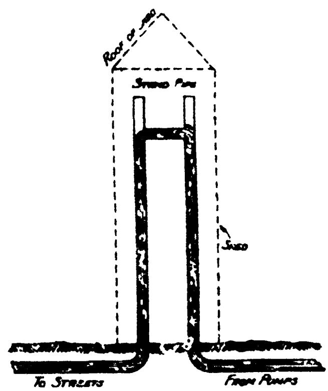


Fig. 18

in 1785, the Vauxhall in 1805, the West Middlesex in 1806, and the Grand Junction in 1811. These Companies continued to supply the Metropolis until their amalgamation under the Metropolitan Water Act, 1902.

Most of the systems of water supply in use at the present time are of modern date, and where it can be arranged, include reservoirs situated at

Fig. 19.

some height above the town to be supplied ; in flat districts where high ground is not available the water is usually pumped into tanks or towers or up through high iron "stand pipes" to give sufficient pressure to force the water to the highest part of the town (see Figs. 17 and 18).

Service reservoirs should be tightly covered in, to prevent evaporation

and contamination, and, by the exclusion of light to retard the growth of vegetation.

As mentioned above, the early conduits were in the form of aqueducts and pipes of earthenware and even stone (see Fig. 19—part of stone water

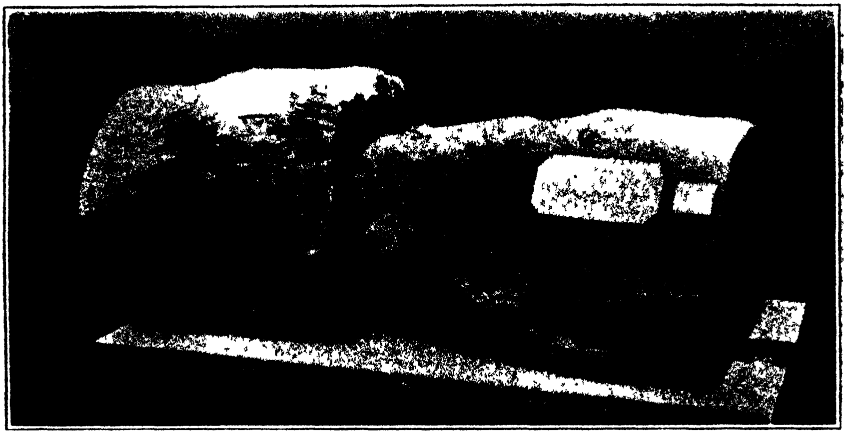


Fig 20.

main as used in the first works for the supply of Manchester, 1810-14). Logs of wood bored out to form pipes were in use some 2,000 years ago, and up to a comparatively recent date, wooden pipes were used extensively in London. Tree trunks from 5 to 10 feet (1·5 to 3 m.) long (see Figs. 20 and 21) had holes

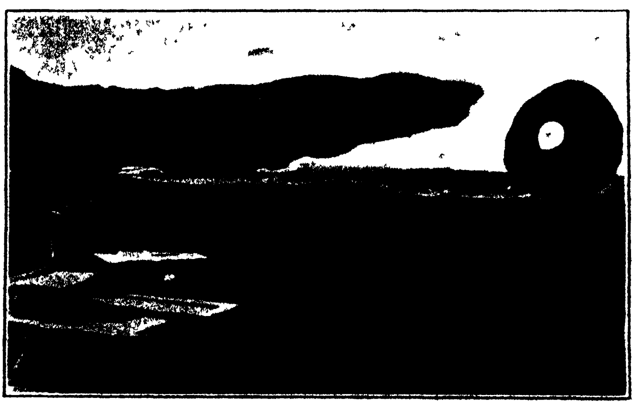


Fig. 21.

about 6 inches (0·15 m.) in diameter bored throughout their full length. One end was pointed to form a spigot and the other hollowed out for a socket. They were joined by driving the tapered end into the socket. In order to prevent the sockets from being forced open, iron rings were driven into that

end of the trunk about $1\frac{1}{4}$ inches from the water-way. These conduits were only able to withstand small internal pressures, and their use was restricted to conveying the water from the reservoirs to the public fountains or cisterns in the streets, from which the inhabitants obtained their supply. Fig. 22 shows two joined at right angles. After a time connections were more or less clandestinely made which diverted the water into private grounds; this much reduced the already poor pressure and caused great waste of water. For fire purposes it became the custom to dig down into the street and find the pipe; then a hole was bored in the wooden pipe with an auger and the water which flowed into the street was collected either by placing over the hole a canvas dam with an opening in the bottom, from which the fire engines drew their supply, or by inserting in the wooden pipe the tapered end of a stand pipe, to which hose could be attached. After the fire was over a wooden plug was driven into the hole in the pipe and the protruding end cut off, and the surface of the roadway restored to its original state.

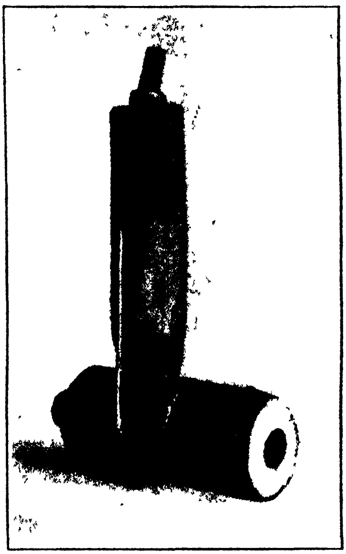


Fig. 22.

Wooden pipes can still be seen in use in most of the Alpine villages of the Tyrol.

In the United States of America wooden pipes have been used since 1818.

The pipes were made of lengths of timber held together by an external binding.

The use of timber was to satisfy the demands in remote districts where the transportation of iron pipes was difficult and costly. These districts usually being well wooded the necessary timber was readily at hand.

The design and construction of the modern "wood stave pipe" is the outcome of many years' experience of the use of wood for this purpose in the United States and Norway. They are now formed of milled staves, staggered longitudinally, to prevent the formation of circular joints in the pipe line, and the ends of the staves are also joined by steel strips so as to form a homogeneous structure. The outside is bound round with steel bands as a reinforcement (see Fig. 23).

Pipes of sizes 2 inches (0·05 m.) to 24 inches (0·61 m.) are made in factories in lengths up to 18 feet (5·9 m.). The staves being tongued and grooved and finished to present a true circular profile both inside and outside.

Hydrants.—About 1800 the improvement in the manufacture of cast iron was followed by the extended use of that metal in making water mains, and thus allowing greater pressures in the pipes. In the early systems right-angle sockets were cast in the pipes and laid at irregular distances in the streets. These sockets were closed by wooden plugs and the whole arrangement called a fire-plug. Fig. 24 shows a water main with the socket and plug in position, together with a cast-iron conical shield from the water main to the street level. To a great extent this prevented the soil under the paving being

washed away. To obtain the water the Turncock first cleared out the rubbish or packing in the hole; then, by tapping the upper end of the wooden plug he loosened the same sufficiently to allow the water pressure to force the plug out on to the surface. In some cases with very low pressures the plug had to be drawn out by the spike on the end of the turncock's spoon; in other

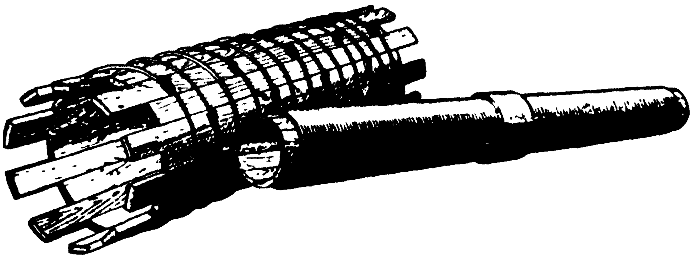


Fig. 23.—View of Wood Stave Pipe. The left picture shows part of a continuous pipe. The right picture shows two sectional pipes connected by a socket.

cases they were ejected with such force and followed by such a volume of water (Figs. 24 and 25) that the job of shipping the stand pipe was a work of great difficulty (see Figs. 26 and 36). The use of fire-plugs was very wasteful, both of water and pressure, and they are now seldom used.

In order to reduce the loss of water from plug hydrants, they were fixed

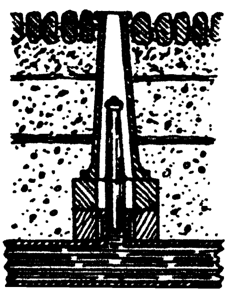


Fig. 24.

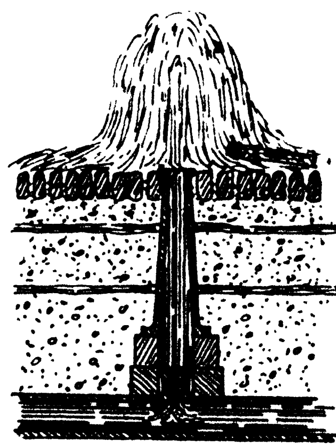


Fig. 25.

upon short lengths of water main controlled by a command cock near to the larger pipe.

The next most simple means of obtaining water is by the "Ball Hydrant" (see Fig. 27). It can be supplied very cheaply, as it only consists of two castings, the lower having a flange for bolting to the upper end of the junction pipe on the water main, and the upper having a bayonet connection for the stand pipe. This casting also acts as a seat for the ball forming the valve.

The balls are of hard wood covered with a thin coating of gutta-percha which gives sufficiently to allow a tight joint to be made against the seating. The

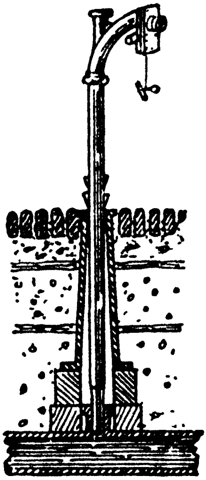


Fig 26.

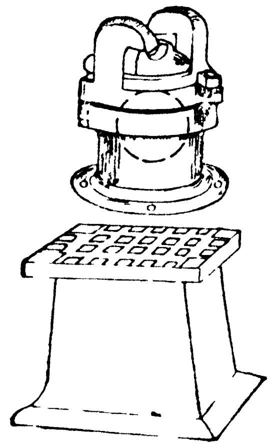


Fig 27

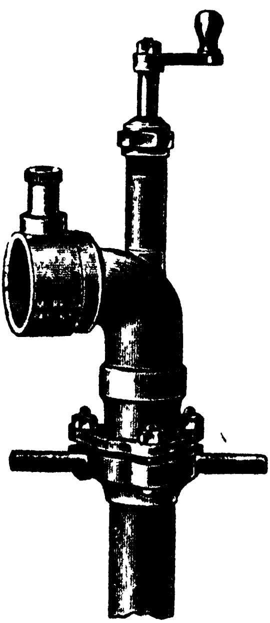


Fig. 28.

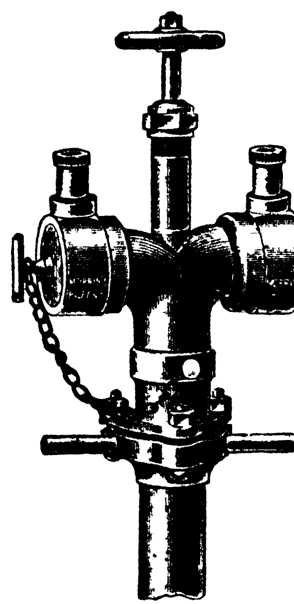


Fig. 29.

pressure of the water forces the ball up to the underside of the upper casting, the lower edge of which is turned to a smooth face to receive the ball. The stand pipe (see Figs. 28 and 33) used with this pattern of hydrant is fitted

with a screw ring at the foot, with two projections that make contact with the lugs on the hydrant and screw upwards, forcing the base of the stand pipe tightly upon the hydrant. Down the centre of the stand pipe is a screwed spindle passing through a stuffing box at the head and finishing above with a handle. The lower end is fitted with a brass cup working loosely upon the spindle. To obtain water the stand pipe is fixed to the lugs and the handle

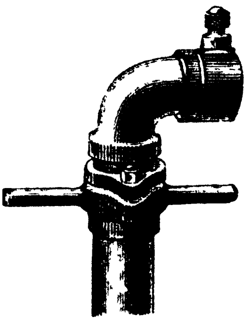


Fig. 30.

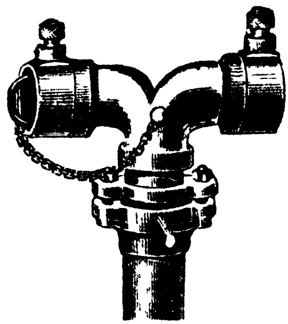


Fig. 31

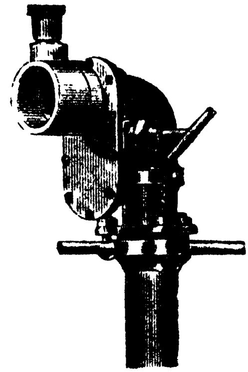


Fig 32.

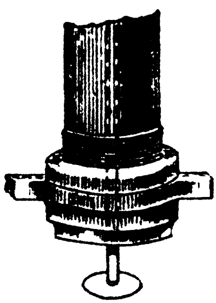


Fig. 33.

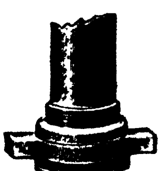


Fig. 34.

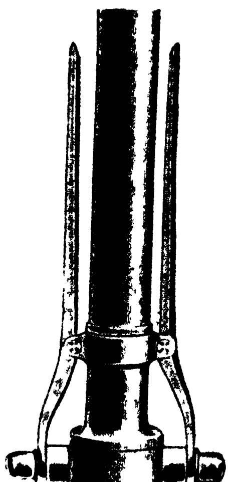


Fig. 35.

Fig. 36.

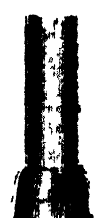


Fig. 37.

turned at the top; the screw forces the spindle down upon the ball and causes the ball to leave its seating, thus allowing the water to flow round the ball and up the stand pipe. This type of hydrant is simple, but has the objection that considerable obstruction to the flow of the water is caused by the ball and cup. It has also been condemned by the Medical Officers of Health on account of a water supply becoming contaminated by germs entering from the street

surface. The contention was that the pressure in the mains having been removed owing to the water in the lower part of the town being turned off, the balls dropped from their seating and allowed the dust and refuse that drifts from the street into the boxes of such hydrants to fall into the water mains; when the water was again turned on the germs were circulated through the whole of the town and were the cause of a severe epidemic.

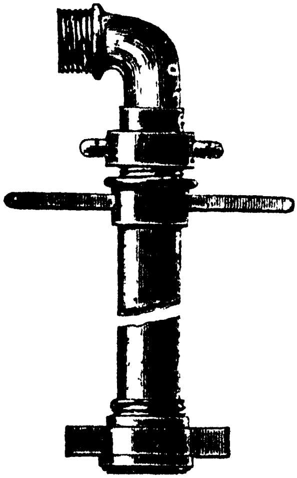


Fig. 38.

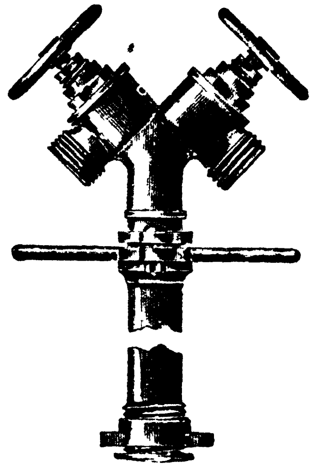


Fig. 39.

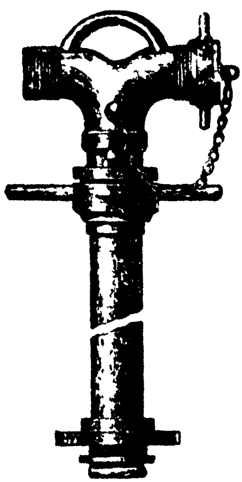


Fig. 40.

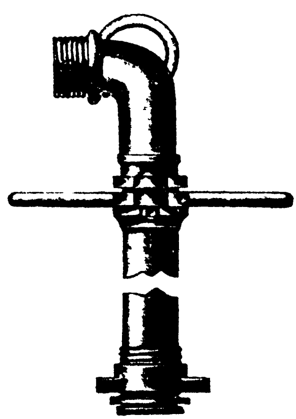


Fig. 41.

Valve Hydrants.—An enormous number of different patterns of hydrants and stand pipes are manufactured, each maker claiming particular points of excellence.

The mode of attaching the stand pipes varies in nearly every town, from the so-called "instantaneous" to the fine V thread. In London the large

round thread as fitted on the hose is used ; it has the advantage of allowing the hose to be coupled direct to the hydrant and thus saves time in a hurry-up job for the first arrivals at a fire.

Drawings of a few typical stand pipes are given in Figs. 28 to 41.

Hydrants should be constructed sufficiently strongly to stand very rough use. They should be free in working, easy to repair, and should above all have a clear waterway, with the least obstruction. Tests that have been made

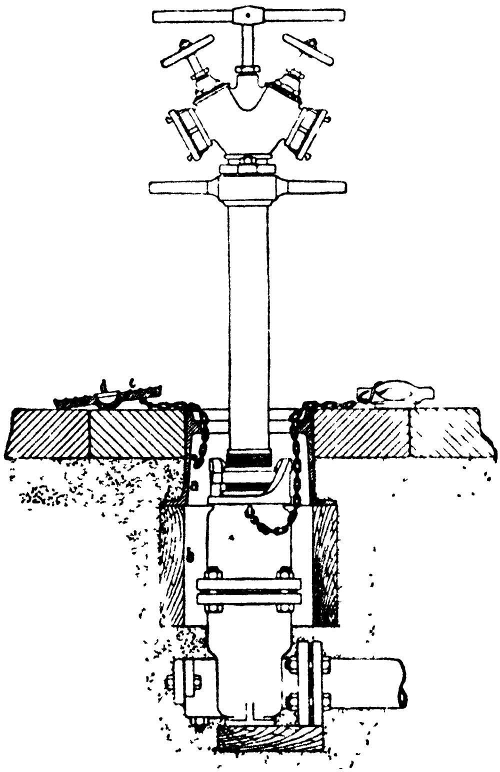


Fig. 42.

have not been of a sufficiently exhaustive nature, but sufficient to show that a loss of 40 per cent. in the flow of water is not unusual, indicating faulty designs which can and should be remedied.

Points to be considered in the design of stand pipes and general fittings :—

(1) Absence of steps, cavities, or roughness of any kind in the interior. These cause eddies and consequently reduce the flow. Keep as far as possible to straight lines.
(2) Clear exterior design devoid of unnecessary excrescences.
(3) Lightness.
(4) Balance.
(5) Use alloys like gunmetal or phosphor-bronze, instead of weak variable brass.
(6) Use solid drawn and not brazed tubing.
(7) All joints to be brazed and pinned.

The valve of a hydrant should always open in the direction of the pressure exerted upon it by the water in the mains. This pressure will assist the valve to rise from its seating when the screw is slackened, so that the hydrant can be opened quickly if necessary. Valves not made on this principle have been known to stick through want of use, and serious results have ensued.

By the pressure of the water being below the valve, the water is kept clear of the gland packing. This prevents leakage through the packing and allows the gland to be repacked without shutting off the whole water supply.

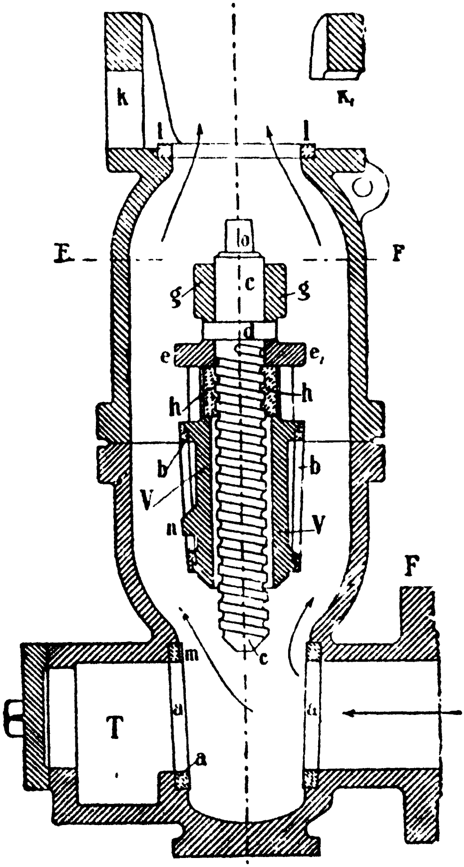


Fig. 43.

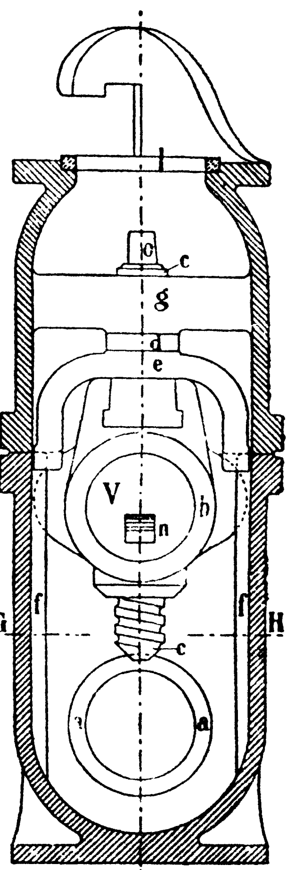


Fig. 44.

Dead water should not lie in the body of the hydrant with the likelihood of being exposed to cold and thus be subject to freezing. It must be remembered that such seldom used apparatus is readily damaged by frost.

Valve hydrants may be divided into two classes, external and internal, and the former again into ground hydrants and those of the pillar type.

External Hydrants.—On the Continent and in the U.S.A. hydrants are often of much larger size than in England, and the custom prevails of having

the spindle of the key down the centre of the stand pipe (see Figs. 42, 43, and 44), the square hollow in the foot of the key slipping over the square boss on the top of the screw spindle.

In the northern towns of Europe the water mains have to be laid at a considerable distance under ground, and the valves to keep back the water must be well out of reach of the frost.

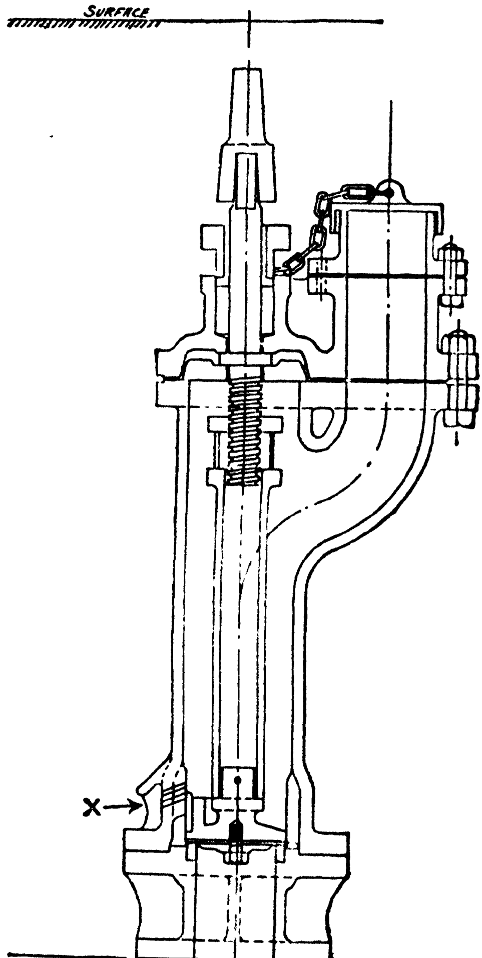


Fig. 45.

The depth will vary in different countries, but in even warm climates they must be low enough to allow the surface pipes, usually attached to the top of the iron pipes, to have sufficient covering to protect them from damage by the road paving or vehicular traffic.

In all cases the valves should be below the frost line and all hydrants

should be fitted with drain cocks, and the pits so arranged as to be kept clear of water.

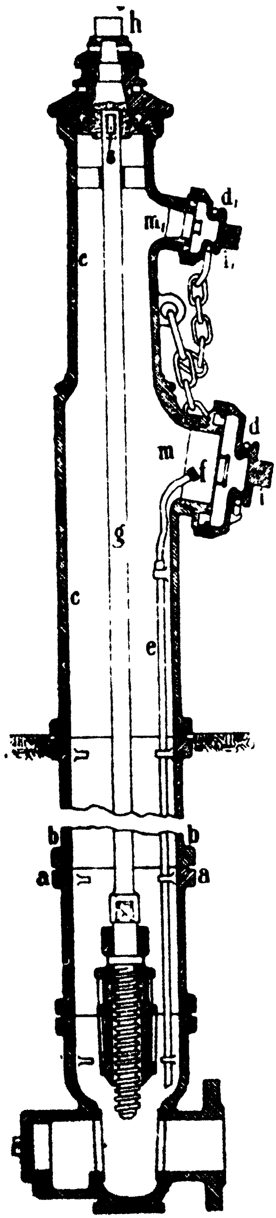


Fig. 46.

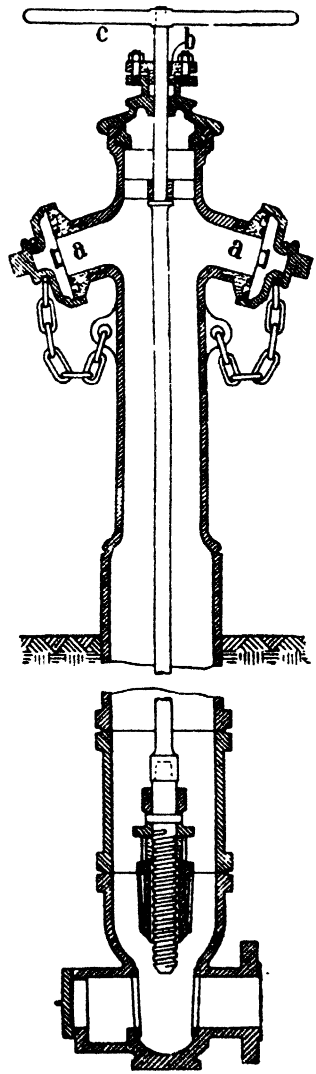


Fig 47.

Fig. 45 shows a popular pattern, the foot of the valve being 3 feet 3 inches

(1 m.) below the surface of the ground. The arrangement of the foot shows how the drainage hole (x)—which is always open when the hydrant is closed —is automatically closed on the hydrant being opened.

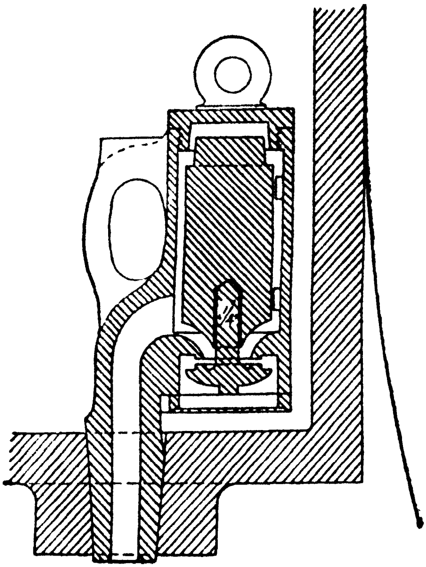


Fig 48.

Figs. 46 and 47 show two patterns of post hydrants with central spindle ; 46 has outlets for 2 different sizes of hose, and 47 is double-headed.

English Practice.—The hydrants now generally fixed in England are of what is known as the Sluice Valve Type, in which the cast-iron supply pipe is brought up to the position selected for fixing the hydrant, and a sluice

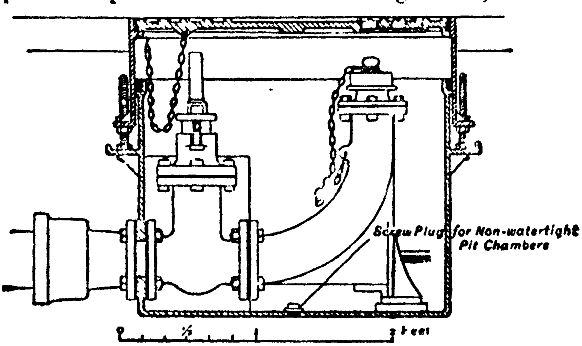


Fig. 49.

valve attached to it, the hydrant being finished by a cast-iron band of varied pattern, having one or two outlets as required. The upper end of the bend is fitted with Lugs, or with a gunmetal screwed outlet. In the bend is fixed the emptying valve, called a frost valve.

Frost valves to be efficient should be self-acting, and fixed at the base of the hydrants to allow the water left in the bends to escape (see Fig. 48). They are brought into action by the pressure of water in the bend passing through a perforated No. 20 gauge copper plate, which is fixed upon the under side of the valve. The pressure of the water acting upon the disc forces it upwards against its seat and seals the opening. Upon the cessation of the pressure, the weight forces down the disc and the leg of the valve acting as a syphon clears the water to the level of the plate. The water that has passed

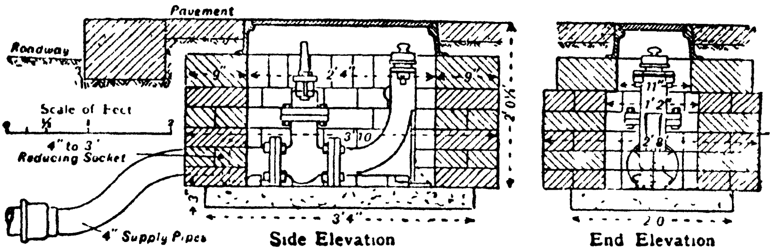


Fig. 50.

out of the hydrant by the valve is still to be dealt with. In a gravel sub-soil this soon soaks away, but in many places the hydrant pits are situated near basements and considerable damage has been caused by the leakage making the walls damp.

Hydrant pits, if not provided with a proper drain, should, when near cellars, be made watertight, and in some cases it is even necessary to have them lead lined.

Where the water contains a large percentage of lime, it will be necessary to use some material other than lead for lining purposes, as the lime acts chemically upon it, causing it to deteriorate to such an extent as to become porous.

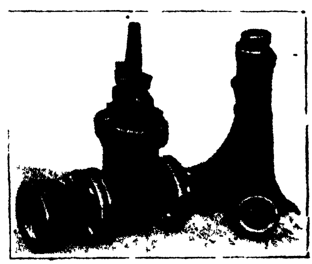


Fig. 51.

In the County of London hydrants of three types are used, the single, as shown in Figs. 49, 50, and 51, and the double, Figs. 52 and 53, which is made up of two single bends and valves joined to each other, and to the main by a Y connection; and the third, which is the City of London pattern, and consists of one valve opening into a cast-iron bend, with the upper end enlarged to form a chamber upon which two screwed outlets are fixed (see Fig. 54). The size of the main for a double hydrant should be not less than 4 inches (1·2 m.) in diameter, or better, 5 inches (0·13 m.), if a good supply is required (see Fig. 53).

Water companies are under liability to fix fire plugs, etc., at the request of the Urban authority, and in order to do so at the least cost they fix them between two lengths of water main in the roadway. As most of the roads in England are macadamised, and the surface of such roads is subject to continual wear and repair, it follows that the hydrants so fixed are soon

either above or below the surface of the road and are also often difficult to find.

In order to obviate these difficulties, branch pipes should be carried from

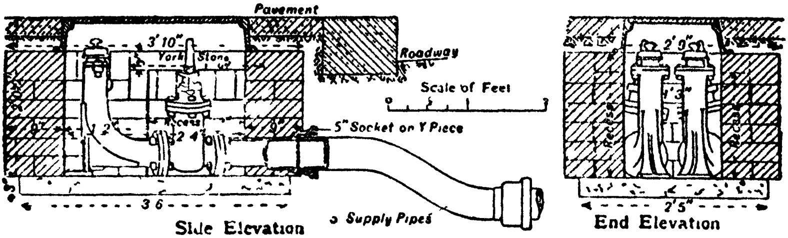


Fig 52.

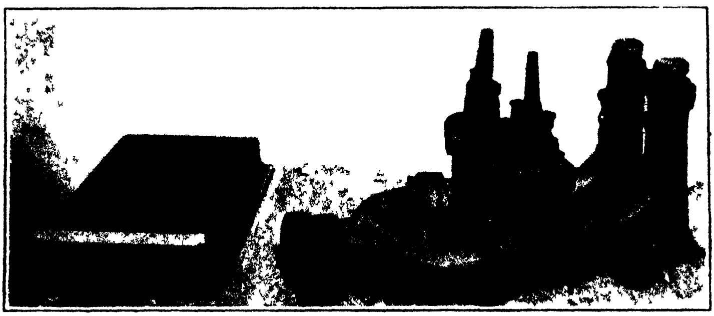


Fig 53.

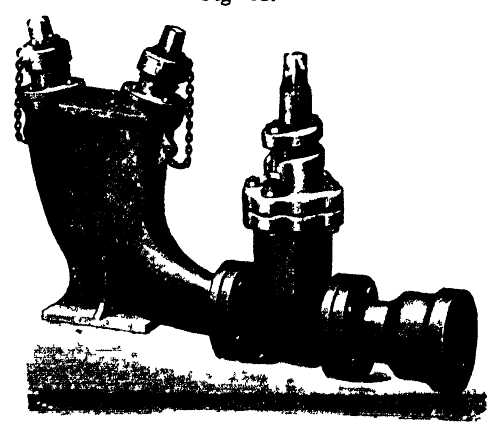


Fig 54.

the mains in the roadway to positions inside the line of the curb, and the hydrant covers brought up level with the surface of the footways. As these are kept constantly swept, there would be no difficulty in locating the covers even after a fall of snow.

The distance apart that hydrants should be fixed depends upon the nature of the property to be protected. In Urban Districts, the distance should not as an average exceed 400 feet. Hose carts and first aid appliances usually carry 500 feet of hose and the distance from the hydrant to the back or top of premises is often 350 feet, so with the loss due to bends, etc., the full length is often used. In cases where the buildings are set back some distonce from the roadway, and also in the case of exceptionally high buildings, a nearer grouping is necessary to ensure that the firemen who first arrive may be able to reach the seat of the fire.

Stand pipes fitted with two high-pressure screw down Bib Taps are used by Local Authorities during severe frost to supply householders with water.

Two-inch water meters can be fitted to the top of stand pipes for recording the amount of water passing through the outlet.

In order to ascertain the value of hydrants from a fireman's point of view, it is necessary to know the pressure in the mains, which may be stated in lbs. per square inch, or in atmospheres; or, alternatively, the head of water in feet may be given. These three can be reduced to the same value, which will give the quantity of water provided by such pressure. The pressure is most conveniently obtained by the use of a Bourdon Gauge.

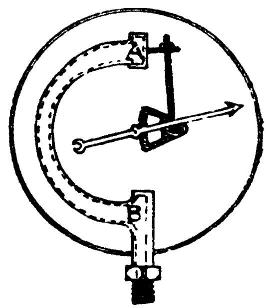


Fig. 55.

A Bourdon Gauge consists of a tube "A," "B," Fig. 55, of thin metal of elliptical section which is bent into an arc. One end of the tube "A" is closed, the other, "B," communicates with the liquid supply, the pressure of which is to be measured. When the pressure in the tube increases, the elliptical section tends to become circular. This causes the tube to uncurl slightly so that the end "A" moves upwards; this slight motion of the tube is communicated to a pointer which moves over a circular scale by means of a lever working a rack and pinion. In order to fix a scale to the dial for future working, various known pressures are applied to the inside of the tube, and the resultant positions of the pointer are painted upon the face, in a semi-circle from the centre of the pointer.

The volume of the flow of water through a hydrant can best be obtained by the use of one of Prentice's flow gauges. The following extract from a paper prepared by Mr. E. S. Prentice, A.M.I.C.E., and printed as a selected paper (No. 3231), by the Institute of Civil Engineers, will explain the construction of the apparatus.

"The most convenient place for the attachment of a gauge is the outlet of a stand-pipe, and the form of gauging device which appeared to lend itself best to this particular purpose was the ancient one known as the Pitot tube, applied to the stream from the stand-pipe and arranged to indicate on a suitable pressure gauge, from the readings of which the discharges might be deduced. When a hydrant is opened, the stream of water escapes from the stand-pipe outlet in a broken and irregular manner, due to its passage round the sharp bend at the top. Sufficient regularity to insure successful gauging is therefore restored to the stream by passing it through a straight pipe, 1 foot (·305 m.) in length, having the same bore as the outlet. Near the outlet of this straight tube or 'flow-pipe' was fixed an experimental Pitot tube (Fig. 56). Tables of discharges for every one-tenth of a foot of water-pressure indicated on a mercurial pressure-gauge were calculated to indicate the pressure in the Pitot tube. These tables were calculated from the law of

falling bodies without the introduction of a coefficient; for example, if 16·1 feet of water-pressure was indicated in the pressure-gauge it was assumed that the current was impinging on the inlet of the Pitot tube with a velocity of 32·2 feet per second, and on the supposition of a uniform velocity over the whole bore (two and five-sixteenths inches in diameter) the discharge was reckoned at 351 gallons per minute.

"The experiments demonstrated that with the Pitot tube midway between the centre and the side of the tube the flow given in the tables against the pressure indicated could be relied on as the real discharge within 3 per cent., and this was true from the smallest to the greatest flows. A sensitive and reliable Bourdon gauge, fitted with a relief-valve to prevent the accidental straining of the delicate Bourdon tube by over-pressure was

Fig. 56.

necessary. To further simplify the use of the instrument the tables were dispensed with, and the discharges were plotted on the dial of the Bourdon gauge against the pressures to which they correspond. Finally, a fine-adjustment screw-down cock. not shown in Fig. 56, was fixed on the looped brass connecting-tube, to check any oscillating tendency of the index.

"The Pitot tube is arranged at the side of the flow-pipe, and the pressure-gauge is connected to it by a looped brass tube so disposed that the Pitot tube, the loop connection, and the Bourdon tube all lie wholly in the same horizontal plane, thus the Bourdon tube always receives the same pressure as the Pitot tube, and, there being no dips in the connections, the presence of air in them does not lead to erroneous indications. The loop connections, while retaining the dial in position, prevents the strong vibrations in the flow-pipe being transmitted to, and injuring, the delicate mechanism of the gauge.

"Instruments of this pattern indicating to 800 gallons (3,633 l.) per minute have for nearly 22 years been in constant use by the London Fire Brigade, and have proved thoroughly reliable and serviceable. It will be found that while some gaugings exhibit high pressures and low supplies, others show low pressures and large supplies; this is of course attributable mainly to the sizes of the street mains.

"For small pressures the mercurial pressure-gauge shown in Fig. 56, gives the more accurate results.

"Apart from the gauging of water for fires, this appliance is employed in investigating stoppages in subsidiary water-mains by deposit or otherwise, by means of comparison of the actual with the calculated flow."

The flow of water through pipes is often reduced by the interior becoming coated with slime, by tree roots, and other organic growth, particularly in districts where the consumption of water is constant and comparatively small in proportion to the original capacity of the pipes.

A small fibre from a tree root will find its way through any slight opening in the joint of a water pipe that may have been caused by an undue strain, and when once in the water will rapidly grow, and has been known to block the pipe.

The author can vouch for the following obstructions found in hydrants :—

Half a cubic yard of shells (presumably from a filter bed).
A live fish 6 inches (0·15 m.) long.
A piece of cast iron 1¼ inches (0·03 m.) square and 3½ inches (0·09 m.) long.
A stick 1¼ inches (0·03 m.) square and 4 feet 6 inches (1·4 m.) long.
Upon one occasion a garden glove came through a 1⅛ inch (0·03 m.) nozzle.

The tuberculation, which occurs to a greater or less extent from the corrosion of the iron, often seriously adds to the reduction of the carrying capacity of the water mains.

Mains which when tested by the flow-gauge show evidence of obstruction should be carefully examined and if necessary properly cleaned.

Cast-iron pipes can readily be cleaned by the use of a mechanical scraper, some of these are actuated by water pressure.

A register and plan showing the position and hydraulic value of all hydrants and water valves should be kept up-to-date at each fire station, and available at all times for the inspection and instruction of the firemen.

When a district changes from being of a residential character to one mainly either commercial or manufacturing, particularly where the spaces at the rear of houses have been built over, additional hydrants and an improved water supply should be provided to meet the increased fire risks.

Building operations and any excavation work in progress near hydrants should be kept under observation, and arrangements made to render accessible any hydrant or valve that might otherwise be obstructed. Any damage or disturbance that has taken place must be made good without delay.

In fixing hydrants it is always possible that the lead used in jointing may have broken through the stuffing, and entered and partially blocked the pipe; so proper tests must be made after new hydrants are fixed, and a complete record kept. From time to time all hydrants should be gauged, and if any diminution of the flow or pressure is found, a strict investigation should be made to ascertain the cause.

A hydrant may show a great head of water, and at the same time be

useless for fire purposes by reason of the small volume actually obtained. Cases have been found in which the water supply to a hydrant has been restricted by connecting the hydrant to the street main by a pipe of only ¾ inch (0·02 m.) diameter. In one case there was no connection at all. This latter case occurred in a public building and was not discovered until a fire occurred, although a number of shining gunmetal and red painted fire hydrants were installed about the building, and a professional fireman employed. Needless to say, the result was disastrous.

Local Authorities can now obtain powers, making the obstruction of fire hydrants a punishable offence.

The Public Health Act and the Towns Improvement Clauses Act require that the positions of hydrants must be marked upon the buildings or walls near to such hydrants.

Where the hydrants are situated in the roadway, much elaboration of marks results, as it is often necessary to give, not only the distance from such mark to the hydrant, but also the direction, by means of an arrow, or by

Fig. 57.

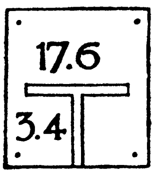


Fig. 58.

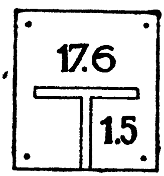


Fig. 61.

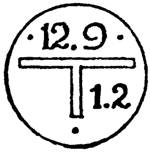


Fig. 59.

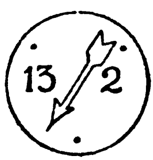


Fig. 60.

Fig. 62.

measurement (see Figs. 57 to 62). In some towns these plates are of different colours to denote special Hydrants and tanks. Fig. 57 indicates that the hydrant is situated 17 feet 6 inches in a straight line outwards from the mark, and 3 feet 4 inches to the left. Fig. 60 is an endeavour to simplify matters by giving a diagonal measurement of 13 feet 2 inches by means of an arrow.

All this elaboration can be overcome by placing the hydrants upon the footway as mentioned above.

In this case, all that is necessary is to place a cast iron or enamelled iron plate, Fig. 63, bearing the letter "H" upon the wall immediately opposite to the hydrant. In the case of double hydrants a "D" may be added (see Fig. 64).

Where the hydrant has been placed at the actual corner formed by the intersection of two paths, it is usual to fix a double plate, Fig. 65, bent to fit the angle of the wall, and having the initial on both sides.

This indicates that the hydrant lies upon a line bisecting the angle at which the paths meet.

If the hydrant is situated on a side of a road devoid of buildings or fences,

its position may be indicated by an oval plate, Fig. 66, fixed upon the side of the building or fence on the opposite side of the road.

If there are no buildings or fences on either side, it will be necessary to erect a post to carry the plate.

If the wall or other surface to which the plate is to be fixed is of light colour, it is usual for the plate to be enamelled blue, with a white letter, or *vice versâ*.

Tablets for indicating the position of hydrants should be placed at least 6 feet above the ground, unless an objection is raised by the occupier of the

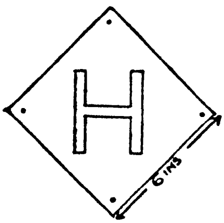


Fig. 63.

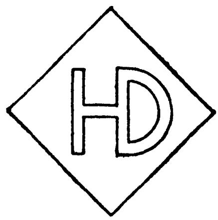


Fig. 64.

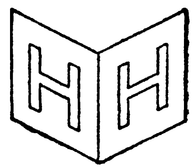


Fig. 65.

premises, in which case an effort should be made to meet the objection so far as is possible without sacrificing the prominence which is necessary.

If a shop window intervenes, the indicator should be placed over the fascia. If the position selected be upon a fence or railing, the height should be as near six feet as possible.

Before the indicator is fixed, a proper notice must be served upon the owner or occupier of the premises (see appendix).

In the days of fire plugs and controlling cocks, it was the custom to place indicators of glass, with red lettering in the lower portion of the lantern of street lamps. These were so placed as to point out the direction in which the plug and cock were to be found.

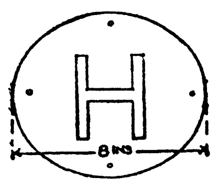


Fig. 66.

As gas was then almost universally used for lighting, it was necessary for the street lamps to be removed and periodically cleaned, and it often happened that, in replacing the lantern, the cleaners forgot on which side the indicators should be placed, and much confusion ensued through hunting for the fixtures in the wrong direction.

Hydrant indication tablets should be cleaned not less than twice a year.

Internal hydrants should be fixed in positions where they can command the largest number of points with the minimum length of hose. They are best placed in positions open to view, not in cupboards or places likely to be blocked by fittings or packing cases. Internal hydrants may be considered as free from the likelihood of frost, therefore the pillar or wall type is preferred; ground hydrants in floors or paving should only be fixed under exceptional circumstances.

In selecting the position for, and pattern of, internal hydrants, care should be taken that when fitted with hose they do not unduly project on to the passageway and catch in the groin persons who are hurrying in the dark.

Internal hydrants are often fitted with bib cocks for use when only buckets of water are required; these cocks must, however, be sufficiently high to allow a full sized bucket being placed under for filling.

Hydrants to which the hose is kept coupled up should have a small test tap upon the underside to draw off any water that might pass the valve, otherwise the hose may be rotted at the coupling and the length of hose be found useless when required.

Internal hydrants in many buildings require a system of mains and branch pipes, which may be simple or elaborate according to the size and character of the building to be protected.

The mains should be so arranged that a constant flow of water is maintained throughout the installation with no "dead water." By "dead water" is meant water which lies stagnant in lengths of piping between the supply pipe and the closed hydrant. Unused mains are always liable to silt up or corrode, besides providing a breeding place for germs that may be injurious and contaminate the public water supply

No advantage is gained in having the fire mains distinct from the domestic supply, unless use can be made of a high-pressure fire supply that cannot with economy be used throughout the building for other purposes. A system in which the water for domestic and fire purposes is drawn from one set of mains insures that the inmates will know when the water is cut off and demand its restoration at the earliest possible moment. Cases have occurred in which, on account of a slightly leaky valve, the fire mains have been shut down and forgotten for weeks and the result has naturally been serious when a fire occurred. If the domestic water supply had been drawn from the same source, the inmates would have at once complained of the lack of water, and the repairs would have been executed very much sooner.

In Europe most of the large buildings are arranged upon the pavilion plan for the purpose of obtaining natural light for the rooms. This plan usually allows of more than one connection being made to the town mains, and a complete circulation of the water is thereby ensured throughout the whole system.

The height of buildings in the United Kingdom does not, except in a few instances, exceed 100 feet (30 m.), a height to which most water undertakings can supply a fair pressure.

In cases where the building is situated upon high ground or the public supply is bad, special apparatus must be used to augment the pressure.

In America, and some other countries, where the owners of valuable land can enforce their interests, high buildings are allowed, and in order to obtain reasonable insurance rates, very elaborate pipe installations are demanded in order to secure upon the upper floors the pressure necessary for fire streams of sufficient ranges.

The protection to be secured from rising mains (or stand pipes, as they are called in the U.S.A.) depends upon the water supply, the ample size of the pipes, valves and hose; constant attention to see that these are in order and available; and a well-drilled fire staff always at hand to manipulate them when required.

The time necessary for a public fire brigade, after receipt of a call, to attend and to ascend to the sixth or higher floor of a building is considerable; and unless the outbreak can be, to some extent, controlled in the meantime,

much damage may be done before the public appliances can be brought into use.

An efficient installation for a high building is necessarily an expensive item in the first cost of the structure, and entails a considerable annual charge for maintenance.

The size of rising mains must be proportionate to the height and extent of the building, and, if anything, should well exceed the theoretical dimensions necessary to overcome the friction in the pipes, and the weight of the column of water; and should allow a sufficient head at the topmost hydrant to maintain 4 ½-inch (0·013 m.) jets at a pressure of not less than 30 lbs. on the square inch, or two atmospheres.

The hydrants should be of the full size used by the public fire brigade, with outlets fitted of the same pattern. Adapters should be fitted to reduce the outlets to 1½ inch (0·04 m.) diameter, so that the employees on the spot may be enabled to bring into use immediately two of their smaller and handier lines of hose. The adapters should have lugs to facilitate speedy removal if necessary, in order that, on the arrival of the fire brigade, the full size hose may be substituted.

Four ½-inch (0·013 m.) jets with a pressure of 30 lbs. on the square inch (or 2 atmospheres), (equal to a head of 69 feet (21 m.)), should give each of the 4 jets a height of 53 feet (16·2 m.), and a 1 inch (0·03 m.) jet a height of 61 feet (18·6 m.), but the latter, when manipulated by an experienced fireman, will have a much more effective extinguishing power.

Shut off nozzles will allow the jets to be controlled and prevent excessive water damage.

The experience in New York City proved that it is impossible to attack a fire successfully with a *portable* fire apparatus above the eighth storey, or about 120 feet (36 m.) above the street level, if the fire had assumed serious proportions.

In order to provide protection for these high buildings the New York Building Code requires :—

" In every building now erected, unless already provided with a 3-inch or larger vertical pipe, which exceeds 100 feet (30 m.) in height, and in every building hereafter to be erected exceeding 85 feet (26 m.) in height, and when any such building does not exceed 150 feet (46 m.) in height, it shall be provided with a 4-inch (0·1 m.) stand-pipe, running from cellar to roof, with one two-way 3-inch (0·08 m.) Siamese connection to be placed on the street above the curb level, and with one 2½-inch (0·06 m.) outlet, with hose attached thereto on each floor, placed as near the stairs as practicable; and all buildings now erected, unless already provided with a 3-inch (0·08 m.) or larger vertical pipe, or hereafter to be erected exceeding 150 feet (46 m.) in height shall be provided with an auxiliary fire apparatus and appliances, consisting of water tank on roof, or in cellar, stand-pipes, hose, nozzles, wrenches, fire extinguishers, hooks, axes and such other appliances as may be required by the Fire Department; all to be of the best material and of the sizes, patterns and regulation kinds used and required by the Fire Department. In every such building a steam pump and at least one passenger elevator shall be kept in readiness for immediate use by the Fire Department during all hours of the night and day, including holidays and Sundays. The said pumps, if located in the lower storey, shall be placed not less than 2 feet (0·6 m.)

above the floor level. The boilers which supply power to the passenger elevators and pumps, if located in the lowest storey, shall be so surrounded by a dwarf brick wall, laid in cement mortar or other suitable permanent waterproof construction, as to exclude water to the depth of 2 feet (0·6 m.) above the floor level from flowing into the ash pits of said boilers. When the level of the floor of the lowest storey is above the level of the sewer in the street, a large cesspool shall be placed in said floor and connected by a 4-inch (0·1 m.) cast-iron drain pipe with the street sewer. Stand-pipes shall not be less than 6 inches (0·15 m.) in diameter for all buildings exceeding 150 feet (46 m.) in height. All stand-pipes shall extend to the street and there be provided at or near the sidewalk level with the Siamese connections. Said stand-pipes shall also extend to the roof. Valve outlets shall be provided on each and every storey, including the basement and cellar and on the roof. All valves, hose, tools, and other appliances provided for in this section shall be kept in perfect working order, and once a month the person in charge of said building shall make a thorough inspection of the same, to see that all valves, hose and other appliances are in perfect working order and ready for immediate use by the Fire Department. If any of the said buildings extend from street to street, or form an L shape, they shall be provided with stand-pipes for each street frontage.

"Stand-pipes will be required in all buildings exceeding 85 feet (26 m.) in height, also in all open or enclosed structures covering large areas, irrespective of height.

"Such buildings as come within above classification, and which do not exceed 150 feet (46 m.) in height, in which stand-pipes (fire lines) now installed are less than 3 inches (0·08 m.) in diameter, must be provided with lines 4 inches (0·1 m.) in diameter, and in such buildings as exceed 150 feet (46 m.) in height the fire line must be 6 inches (0·15 m.) in diameter, unless the lines already installed are considered satisfactory and approved by the Fire Department.

"These stand-pipes must be of wrought-iron or steel of sufficient strength to withstand the necessary pressure (in no case less than 300 lbs. to the square inch (20·4 atmospheres)) to force adequate streams of water to any of the floors of the building, or to the roof, and must extend from cellar to roof and be connected with outside two-way 3-inch (0·08 m.) standard Fire Department connections, with clapper valves and proper caps, placed on street front of buildings, above curb level, in a position accessible for use of Fire Department. These stand-pipes must be provided with proper valves (gate valves preferred) and 2½-inch (0·06 m.) outlets of the regular Fire Department pattern and thread on each floor level, with sufficient standard 2½-inch (0·06 m.) hose and nozzles attached thereto to properly cover entire floor area, arranged on proper and approved racks or reels, with approved open or controlling nozzles. Proper check-valves shall be placed in top and bottom of such lines as are required.to use tank or pump supply, or both. The hose outlets and hose must be located within stairway enclosures, except where impracticable to do so for reasons satisfactory to the Department.

"Where more than one stand-pipe is installed, cross connections, preferably in basement, of same size as main risers, or larger, must be provided."

Buildings like the Woolworth Building of 55 storeys and 775 feet (236 m.) in height above the street level, and others in New York, partake more of the

nature of enormous towers that require special engineering knowledge to provide adequate protection.

Water can, of course, be forced through pipes to great heights, but in order that the supply may be ready at hand for instant use the stand-pipes must always be charged. The hydraulic pressure in a main of great height would be such as to produce a pressure in the lower parts of the building that would damage any ordinary hose.

In order to overcome these great pressures, and to provide a supply that can safely be controlled when in use through fire hose, if has been found advisable to divide high buildings into a number of vertical sections each with its own tank supply.

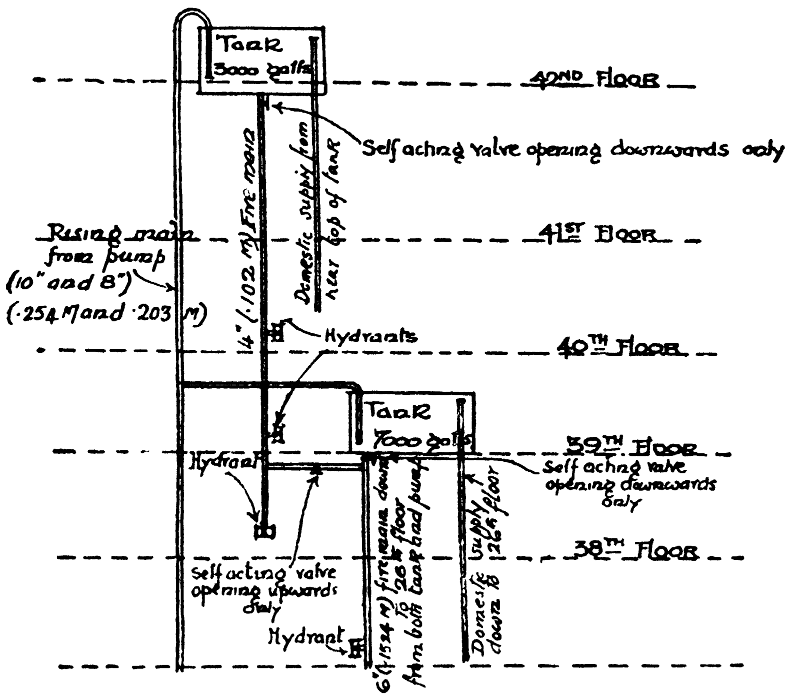


Fig. 67.—Arrangement of pressure tanks and check valves, etc., in a high building.

The Singer Building, New York, of 42 stories, 611 feet (186 m.) high, was one of the first of its kind to be dealt with in sections.

A 3,000 gallon tank placed upon the 42nd floor supplies the floors down to the 38th by a 4-inch (0·1 m.) pipe upon which are the necessary hose connections; this pipe is joined by a branch to a 6-inch (0·15 m.) rising main to the tank on 39th floor. On the 39th floor a 7,000 gallon tank supplies 12 floors, 37th to 26th, and so on to the ground. Fig. 67 will explain how a system such as this is installed.

The water supply is a threefold one, the fire engine connections for the use of the public brigade pumps, the house pumps when at work, and the water stored in the tanks upon the roof and various floors. The supply for the

house pumps and tanks is drawn from large tanks situated in the basements.

The rising mains must be of considerable size, for the 42nd floor 10-inch (0·25 m.) and 8-inch (0·2 m.); for the 27th floor 6-inch (0·15 m.); while the 13th floor can be supplied by 3-inch (0·08 m.) or 4-inch (0·1 m.) mains. Each set of mains must have its own particular pump in duplicate. All pumps should be so arranged that they can discharge direct into the rising mains.

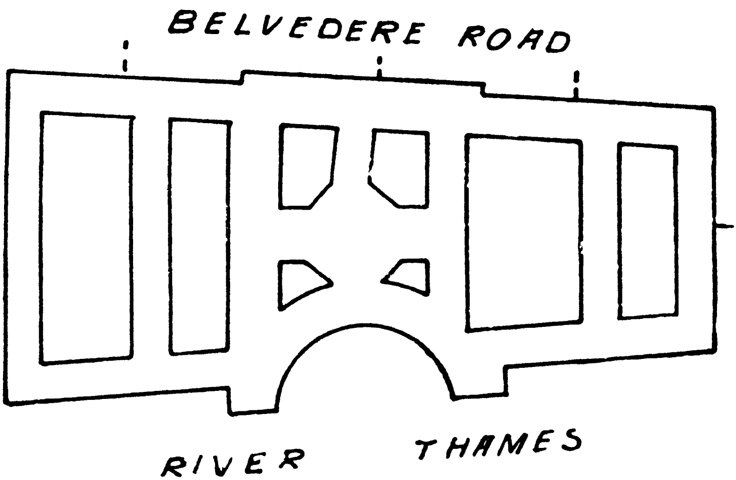


Fig. 68.

Valves are arranged under each tank opening *downwards* to prevent the engines or pumps when pumping into the mains from over-filling the tanks through these rising mains.

The valves opening *upward* at the foot of each fire main allow the mains to be charged from below, but prevent the return of the water to any hydrants below their own section.

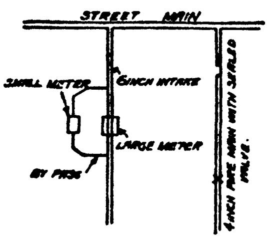


Fig. 69.

The New County Hall, London (block plan, Fig. 68), is an example of a large building of 7 pavilions with 7 floors above the street, and 2 below that level, connected on both sides by buildings facing the street and river respectively. This arrangement allows for a good water supply to be drawn from 4 points. Six-inch (0·15 m.) ring mains encircle the building at the basement and roof levels, with 4-inch (0·1 m.) rising mains, or stand-pipes, in each pavilion, upon which the fire hydrants are fixed. The domestic water supply is drawn from these same mains, so that a constant flow of water is maintained throughout the whole system. The size of the intakes from the street is 6 inches (0·15 m.) with bye-passes as shown in Fig. 69. Four-inch fire mains are also provided direct from the streets with sealed valves that can be opened in case of fire. The whole is so arranged that any one section can be shut off for repairs without interfering with the supply to the other parts of the building. The closing down of a section will at once deprive the

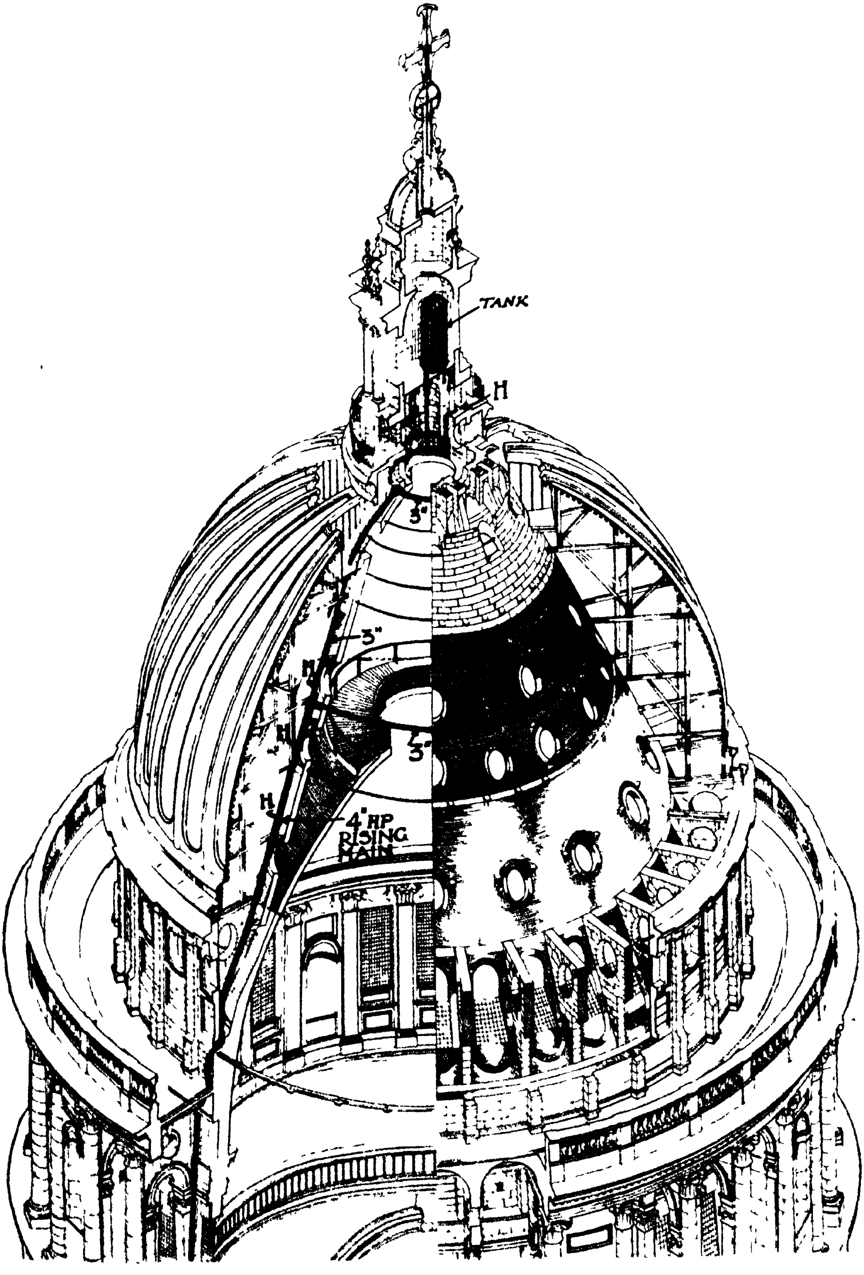


Fig. 70.

lavatories, etc., of their water, so that the necessities of the staff will ensure that the supply is restored at the earliest possible moment.

A dry fire main is provided from the street to the river side of the building in order that a fire brigade pump can be connected to the inlet in the street and thus furnish to a number of special hydrants an independent water supply without laying hose through the corridors.

St. Paul's Cathedral is another instance of protecting a large and high building (see p. 327, Chapter XVII.). The height may be taken at 366 feet (111·5 m.) above the pavement level, and the fire risk, with the exception of the organ, is in the crypt, the wooden roofs, and the timber supporting the outer dome. Fig. 70 is a sectional drawing of the dome. In the City of London, the New River section gives an abundant supply of water, but the pressure near St. Paul's is only 30 lbs. on the square inch (2 atms.), or 70 feet head. The system of fire protection was recently reorganised, and the first thing decided was to divide the risk in the Dome, so that any fire occurring could be kept within bounds. The roof was cleared of as much combustible material as possible. As will be seen from Fig. 70, the dome is in three sections, the inner one, seen from the floor of the nave, the brick intermediate cone, and the outer-lead covered dome seen from the street. Inside this outer dome, which is constructed of timber trusses, covered with boarding and lead, lay the greater risk, not only from fire within, but from the likelihood of brands or sparks that might be carried in by the wind through the ventilating dormers from any warehouse on fire in the vicinity. Should this occur, a fire, however small, would fill the whole of this immense space with smoke, and render the location of the actual seat of the fire most difficult. As stated above, the space was divided into four sections by partitions of plaster upon wire lathing, each with a separate entrance at the base from the open stone gallery.

Water pipes were run half round the inside at 3 levels, and were connected to a new hydraulic pump placed in the basement.

Further, to save time, a dry rising main 4 inches (0·1 m.) in diameter was fixed in the well of one of the staircases from a point 3 feet above the outside pavement to the roof, where a length of hose and a branch pipe were placed ready to be taken round the corridors into any of the roofs. This main is in no way connected to the pump in the basement, but is only for the use of the London Fire Brigade, so that one or two firemen can run up the staircase and get ready for work as soon as the fire engine is in position, and the hose coupled up to the lower inlet. This arrangement much reduces the time required to get water from an outside source.

In the crypt, a portion of which is used as builder's workshops and stores, all that was necessary was effected by a little re-arrangement.

In Theatres, rising dry mains can also with advantage be built into the wall dividing the auditorium from the stage, as explained in Chapter XVII.

Figs. 71 to 76 show patterns of good internal hydrants.

The remarks on page 74 upon the construction of hydrants and the loss of efficiency due to faulty design and fixing apply very forcibly to many internal hydrants.

All hydrants should be inspected six times a year, and every four months a stand-pipe should be properly fixed to see that the frame of the cover has

not been forced out of position. At the same time, water should be passed through the stand pipe to ensure that the flow is satisfactory.

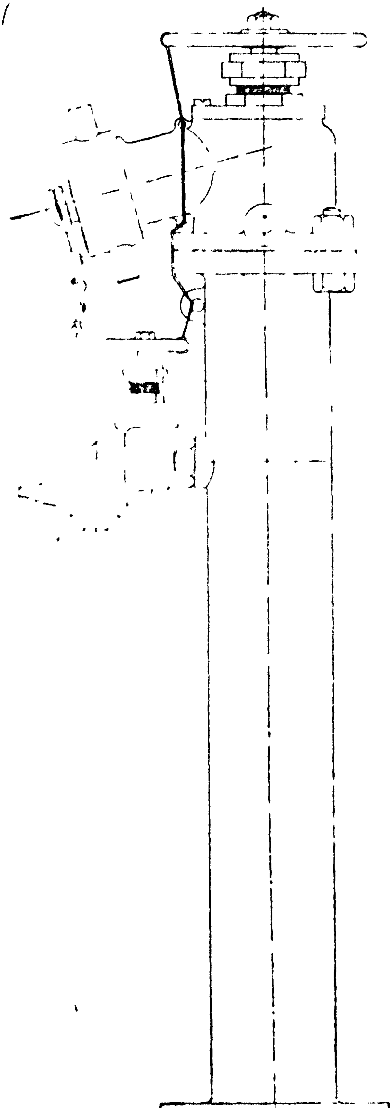


Fig. 71.

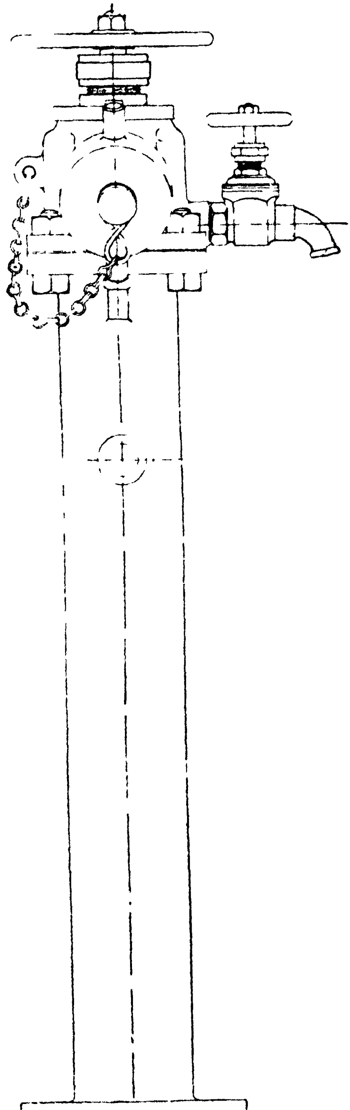


Fig. 72.

Stand-post Hydrant for Internal use.

The spindle of the valves should be oiled at least once every six months. When there are indications of a prolonged frost, special examinations should be made, but water should be used sparingly.

Hydrants that have been used at fires or for any other purpose should be inspected the following day to ensure that they are clear and that the pits are free from water and dirt.

In cases where steamer suctions are coupled direct to hydrants, the delivery outlet on the pump should be opened before the hydrant is turned

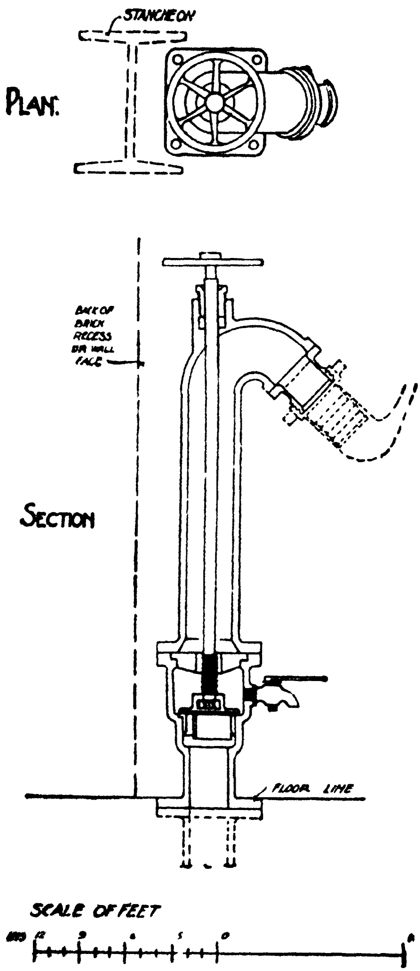


Fig. 73.—Hydrant with Drainage Cock.

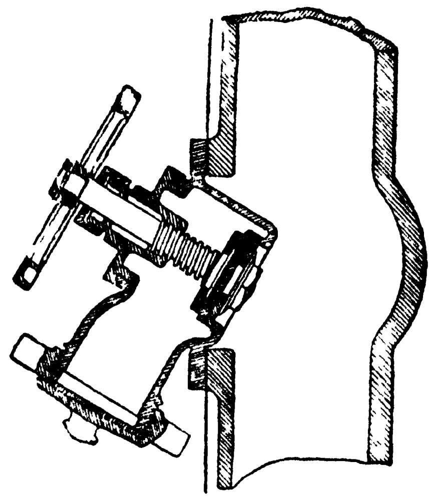


Fig. 74.

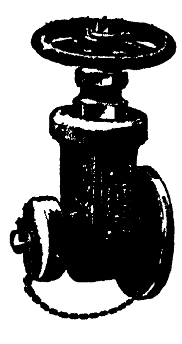


Fig. 75.

Fig. 76.

on, and not closed until the hydrant is shut off. As explained on p. 345, suctions are not intended to withstand any considerable internal pressure.

The pits after use should be properly cleaned and dried. Drying is not such an easy matter as it would at first appear. A useful hydrant pit cleaner is upon the market, constructed to work by the action of the water from the

hydrant (Fig. 77). This appliance consists of a 1-inch (0·03 m.) brass tube 24 inches (0·6 m.) long, fitted at its base into a cast gunmetal cone, having a base area of 4 inches (0·1 m.) × 2 inches (0·05 m.), into which a tube is introduced, having two bends so fixed as to direct a jet of water through the cone into the orifice of the tube.

In the base of the cone are six half-round openings ¼ inch (0·01 m.) in diameter (G), above which is a plate (H) perforated with small holes, to prevent refuse being drawn into the tube. The action of the jet causes a partial vacuum in the cone, and thereby induces the pit water to enter

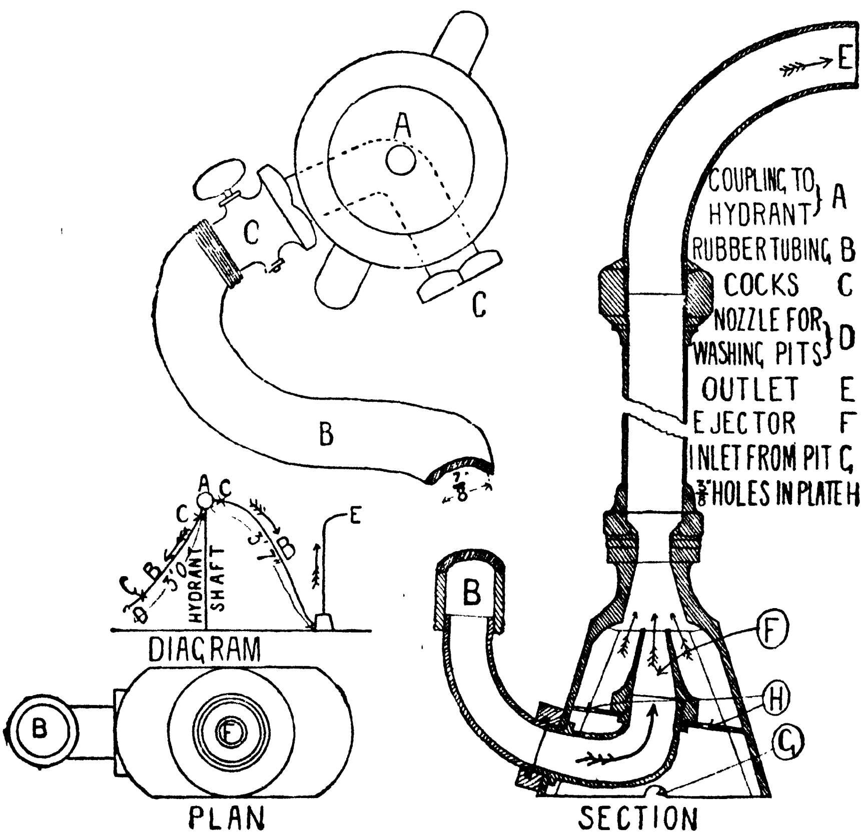


Fig. 77.

the cone, and to be ejected up through the tube and out, through the bend at the top, on to the road surface. The method of operating this appliance is as follows:—A female coupling (A) is fixed to the head of the ordinary hydrant stand-pipe. There are two 4-ply rubber pipes fixed to this coupling, each fitted with a stopcock (C, C). By opening one and closing the other a stream of water can be directed through the nozzle (D) to wash down the sides of the pit. When this has been thoroughly done, the cock on (D)

is closed and that of (B) opened, when the operation of ejecting the dirty fluid from the pit begins, as described above.

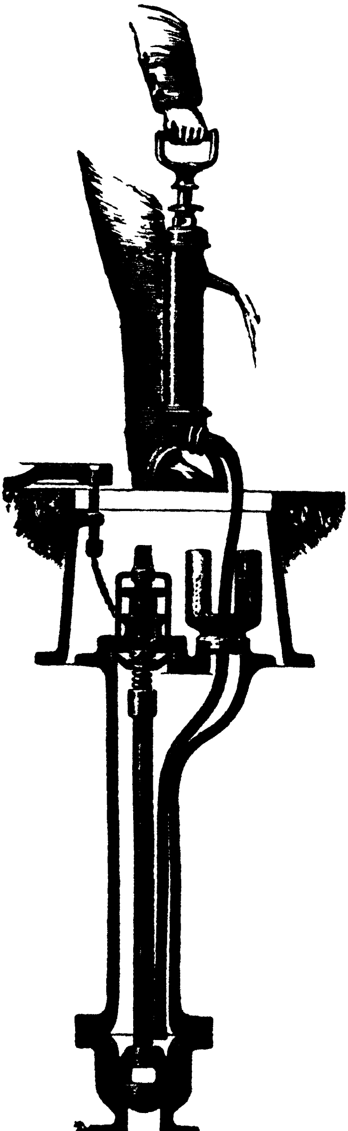


Fig. 78.

A syringe, an ordinary copper suction pump with a long spout or a pump fitted with a long suction hose (Fig. 78), may be used for emptying the pits of underground hydrants.

An ordinary fire brigade hand pump can also be used, provided the space is sufficiently large to allow a man to work it.

General.—Care should be taken not to open or close suddenly at any time the valve controlling the issue of water, or damage may be caused to the mains.

When an adequate public water supply is not available, the pressure in the main may be kept up by the use of pressure tanks or by an automatic fire pump; but it is important that an adequate supply of water should be obtained at once upon opening the valve. Otherwise the operator may be in doubt as to whether water is available at all, and leave the branch on the floor whilst he goes to ascertain the cause, only to find that the water was delayed.

In towns having large fire risks and an indifferent water supply, it has been considered advisable to provide a number of underground tanks in which a store of water can be kept immediately available for the pumps to draw upon as soon as the Brigade arrives with them (see p. 38).

In districts having isolated high points where the water pressure is naturally low, similar storage tanks, situated upon the high ground, are equally necessary (see Fig. 79).

The size of these tanks depends upon the character of the property to be protected and the length of time necessary for the authorities to concentrate the water supply upon the area of the fire.

Authorities differ as to the precise weights and pressures of water, owing to different temperatures being adopted when fixing a standard, but the following equivalent pressures may, for practical purposes, be used.

One atmosphere equals	14·71	lbs on the square inch.
" "	33·88	feet head of water.
" "	29·922	inches of Mercury.
" "	760	millimetres of Mercury.
" "	1·0328	kilogrammes on the square centimetre.

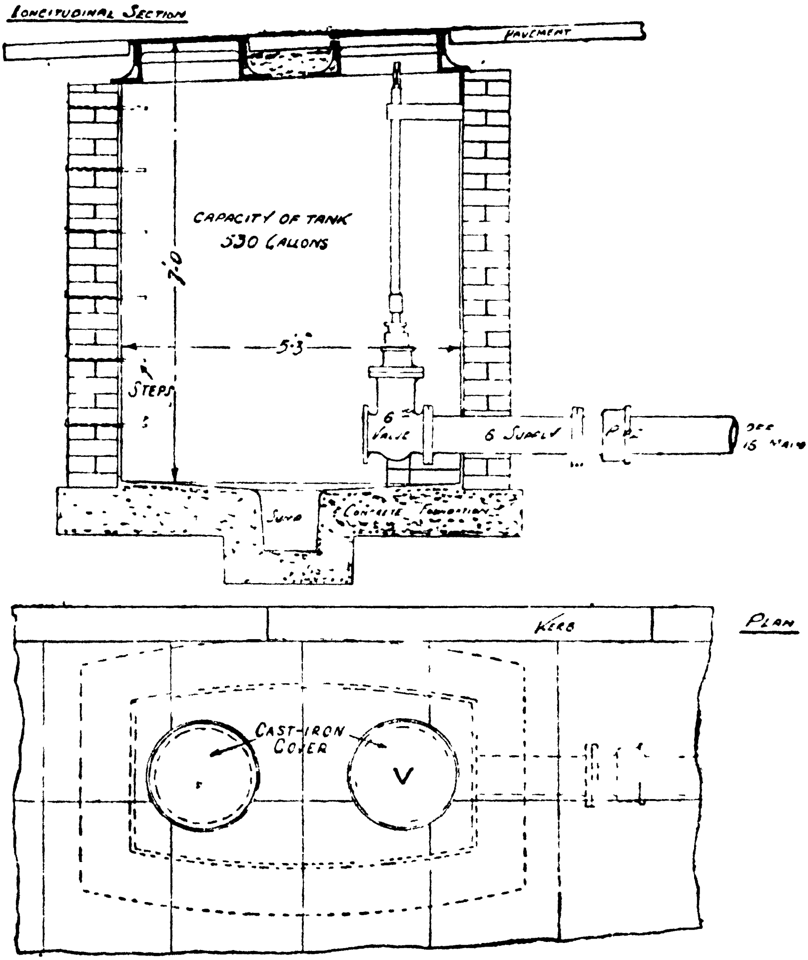


Fig. 79.

A column of water 1 foot high	0·434	lb. on the square inch.
" " "	0·0295	atmosphere.
" " "	0·8823	inch of Mercury.
" " "	22·42	millimetres of Mercury.
" " "	·03048	kilogramme on the square centimetre.

Upon the above-mentioned equivalents the following tables are based. The tables must be taken as approximate and *must not* be multiplied.

To find the approximate equivalent of any pressures, add or subtract from the numbers given in the following tables :—

Thus if the equivalents be required to a head of water 137 feet 9 inches = 137·75 feet, they will be :—

Head of Water in feet.		Atmospheres.	Lbs. on the square inch.	Inches of Mercury.	Millimetres of Mercury.	Kilogrammes on the square centimetre.
100	=	2·95	43·40	88·26	2,242	3·048
30	=	·88	13·02	26·48	672	·914
7	=	·20	3·04	6·18	156·93	·213
·7	=	·02	·304	·618	15 69	·0213
·05	=	·0014	·0217	·0441	1·12	·0015
137·75		4·0514	59·7857	121·5821	3087·74	4·1978

TABLE OF EQUIVALENT PRESSURES COMPARED WITH HEAD OF WATER IN FEET.

Height of a column of Water in feet.	Atmospheres.	Lbs on the square inch.	Inches of Mercury.	Millimetres of Mercury.	Kilogrammes on the square centimetre.
Head.					
1	·0295	·434	·882	22·42	·03048
2	·05	·87	1·76	44·84	·061
3	·08	1·30	2·65	67·26	·091
4	·11	1·74	3·53	89·68	·122
5	·14	2·17	4·41	112·09	·152
6	·17	2·60	5·29	134·51	·183
7	·20	3·04	6·18	156·93	·213
8	·23	3·47	7·06	179·35	·244
9	·26	3·91	7·94	201·77	·274
10	·29	4·34	8·83	224 19	·305
20	·59	8·68	17·65	448	·610
30	·88	13·02	26·48	672	·914
33·88	1·00	14·71	29·921	760	1·0328
40	1·18	17·36	35·30	897	1·219
50	1·47	21·70	44·13	1121	1·523
60	1·77	26·04	52·95	1345	1·828
67·76	2·00	29·42	59·84	1520	2·076
70	2·06	30·38	61·78	1569	2·133
80	2·36	34·72	70·60	1793	2·438
90	2·65	39·06	79·43	2018	2·743
100	2·95	43·40	88·26	2242	3·048
101·64	3·00	44·13	89·76	2280	3·098
135·52	4·00	58·84	119·68	3040	4·131
169·40	5·00	73·55	149·60	3800	5·164
200	5·90	86·80	176·52	4484	6·096
203·28	6·00	88·26	179·53	4560	6·197
237·16	7·00	102·97	209·45	5320	7·230
271·04	8·00	117·68	239·37	6080	8·262
300	8·85	130·20	264·79	6736	9·144
304·92	9·00	132·39	269·29	6840	9·296
338·8	10·00	147·10	299·21	7600	10·328
372·68	11·00	161·81	329·14	8360	11·361
400	11·80	173·67	353·04	8968	12·192

Approximate. Do not multiply these figures.

TABLE OF EQUIVALENT PRESSURES COMPARED WITH "ATMOSPHERES."

Atmospheres.	Height of a column of water in feet. Head.	Lbs. on the square inch.	Inches of Mercury.	Millimetres of Mercury.	Kilogrammes on the square centimetre.
·1	3·388	1·471	2·992	76	·103
·2	6·776	2·94	5·984	152	·206
·3	10·164	4·41	8·976	228	·310
·4	13·552	5·88	11·968	304	·413
·5	16·940	7·35	14·960	380	·516
·6	20·328	8·83	17·952	456	·620
·7	23·716	10·30	20·944	532	·723
·8	27·104	11·77	23·936	608	·826
·9	31·492	13·24	26·928	684	·930
1·0	33·88	14·71	29·92	760	1·0328
1·36	46·06	20·0	40·68	1034	1·40
2·0	67·76	29·4	59·84	1520	2·07
2·04	69·09	30·0	61·02	1551	2·11
2·72	92·12	40·0	81·36	2068	2·81
3·0	101·64	44·1	89·76	2280	3·10
3·4	115·16	50·0	101·70	2585	3·51
4·0	135·52	58·8	119·69	3040	4·13
4·08	138·18	60·0	122·05	3102	4·21
4·76	161·21	70·0	142·39	3619	4·93
5·0	169·40	73·5	149·61	3800	5·16
5·44	184·24	80·0	162·65	4136	5·62
6·0	203·28	88·2	179·53	4560	6·20
6·12	207·27	90·0	183·07	4653	6·32
6·8	230·33	100·0	203·41	5170	7·02
7·0	237·16	102·9	209·45	5320	7·23
8·0	271·04	117·6	239·37	6080	8·26
9·0	304·92	132·3	269·30	6840	9·30
10·0	338·8	147·0	299·21	7600	10·33
11·0	372·7	161·7	329·14	8360	11·31
12·0	406·6	176·5	359·06	9120	12·39
13·0	440·4	191·2	388·98	9880	13·43
13·6	460·7	200·0	406·82	10340	14·04

Approximate. Do not multiply these figures.

TABLE OF EQUIVALENT PRESSURES COMPARED WITH LBS. ON THE SQUARE INCH.

Lbs. on the square inch.	Atmo-spheres.	Height of a column of Water in feet. Head.	Inches of Mercury.	Millimetres of Mercury.	Kilogrammes on the square centimetre.
1	·068	2·3	2·0341	51·7	·0702
2	·136	4·6	4·0682	103·4	·1404
3	·204	6·91	6·1023	155·1	·2106
4	·272	9·21	8·1364	206·8	·2808
5	·340	11·51	10·1750	258·5	·3511
6	·408	13·82	12·2046	310·2	·4213
7	·476	16·12	14·2387	361·9	·4915
8	·544	18·42	16·2728	413·6	·5617
9	·612	20·72	18·3069	465·3	·6319
10	·680	23·03	20·3410	517·0	·7021
14·71	1·00	33·88	29·9217	760	1·0328
20	1·36	46·06	40·682	1034	1·404
29·4	2·00	67·76	59·843	1520	2·066
30	2·04	69·09	61·023	1551	2·106
40	2·72	92·12	81·364	2068	2·808
44·1	3·00	101·64	89·765	2280	3·098
50	3·40	115·16	101·703	2585	3·510
58·8	4·00	135·52	119·687	3040	4·131
60	4·08	138·18	122·046	3102	4·213
70	4·76	161·21	142·387	3619	4·925
73·5	5·00	169·40	149·609	3800	5·164
80	5·44	184·24	162·647	4136	5·617
88·3	6·00	203·28	179·530	4560	6·197
90	6·12	207·27	183·068	4653	6·319
100	6·8	230·33	203·408	5170	7·021
102·9	7·0	237·16	209·452	5320	7·230
117·7	8·0	271·04	239·374	6080	8·262
132·4	9·0	304·92	269·295	6840	9·295
147·1	10·0	338·80	299·217	7600	10·328
161·8	11·0	372·68	329·139	8360	11·308
176·5	12·0	406·56	359·060	9120	12·394
191·2	13·0	440·44	388·982	9880	13·426
200	13·6	460·66	406·818	10340	14·042

Approximate. Do not multiply these figures.

The following are useful data in connection with water supply :—

A Cubic Foot of Water = 6·2355 Imperial Gallons = 7·48 U.S. Gallons = 998·8 oz. = 62·35 lbs. = ·557 cwt. = ·028 ton = ·0283 Cubic Metre = 28·375 litres. Sea water = 64·11 lbs. = 1·026 of pure water.

A Cubic Inch of Water = ·003607 of an Imperial Gallon = ·004329 U.S. Gallon = ·03607 lb. = 252·89 grains.

An Imperial Gallon of Pure Water (Board of Trade standard) at 62° F. (16·6° C.) = 277·274 cubic inches = ·16046 cubic foot = 10 lbs. = 4·537 litres = 1·2 of a U.S. gallon.

As a rule river water contains salts and other impurities which add from ·05 to ·20 lb. per cubic foot to the weight, and sea water 1·5 to 1·8 lbs. per cubic foot. Ice weighs about 57·2 to 57·6 lbs. per cubic foot.

A Ton of Water = 224 Imperial Gallons = 268·8 U.S. Gallons = 35·9 cubic feet = 1,000 litres approx. = 1 cubic metre approx.

A Cwt. of Water = 11·2 Imperial gallons = 13·44 U.S. Gallons = 1·8 cubic feet.

A Pound of Water = ·10 of an Imperial Gallon = ·83 U.S. Gallon = 27·72 cubic inches = ·4537 of a Kilo. A kilo of water = 2·204 lbs.

A Cubic Metre of Water = 220 Imperial Gallons = 264 U.S. Gallons = 1·308 cubic yards = 61,028 cubic inches = 35·31 cubic feet = 1,000 litres = 1,000 kilos. = 1 ton approximately.

A Cubic Litre = ·22 of an Imperial Gallon = ·264 U.S. Gallon = ·0353 of a cubic foot.

A United States Gallon = ·83254 of an Imperial Gallon = 231 cubic inches = ·133 cubic foot = 8·33 lbs. = 3·8 litres.

The density of water at 39·2° F. (4° C.) is 62·321 lbs. per cubic foot and is taken as the standard for Specific Gravity and Specific Heat.

One cubic centimetre of water at 4° C. weighs 1 gramme, the standard for the Metric system.

The pressure of water against walls and sides of cisterns may be considered as acting at a point two-thirds of the total depth from the top.

Water attains its minimum bulk when the temperature = 39·2° F. (4° C.) between which and 32° (0° C.) it expands by cold; at the latter temperature the increase = one-tenth part of the bulk at 39·2° F. (4° C.). Sea water = 1·026 the weight of fresh water.

Cubic feet per minute × 9,000 = gallons per 24 hours.

Cubic feet per second (sometimes "cusec") × 540,000 = gallons per 24 hours.

Cubic feet per second × 375 = gallons per minute.

Diameter in inches squared ÷ 30 = gallons per foot run of full pipe.

Diameter in inches squared = lbs. of water per yard run of full pipe.

Diameter in inches, divided by 10 = gallons per yard run.

Pressure in lbs. per square inch = ·434 × head in feet.

Head in feet = 2·3 × pressure in lbs. per square inch.

Area of a pipe = diameter squared × ·7854.

Water 1 inch deep covering an acre = 22,624 gallons = 101 tons.

Inches of Rainfall × 2,323,200 = cubic feet per square mile.

" " × $14\frac{1}{2}$ = millions of gallons per square mile.

" " × 3,630 = cubic feet per acre.

12 inches of snow = 1 inch of rain.

Friction.—It is difficult to explain in a short chapter the loss due to friction in hose. The effect of so many forces has to be considered before even an approximate figure can be stated.

Experiments made by the Southwark Water Company in January, 1844,

and in March, 1844, by the Preston Water Company, on the height and discharge of jets and other tests with leather hose, are out of date. Leather hose is never perfectly circular, and the variations are so great that any tables compiled from tests made from one make or kind of hose are of no value at all for comparison with another make. Moreover, the diameter of flexible hose is very seldom mathematically correct, and in some kinds it is increased under pressure. When dealing with the fifth powers* this fact is of very great importance.

The most generally used formula for the loss of head by friction is that of Box, which has the merit of erring upon the side of safety :—

$$G = \left(\frac{(3d)^5 \times H}{L}\right)^{\frac{1}{2}}$$

$$H = \frac{G^2 \times L}{(3d)^5}.$$

$$d = \left(\frac{G^2 \times L}{H}\right)^{\frac{1}{5}} \div 3.$$

$$L = \frac{(3d)^5 \times H}{G^2}.$$

In these rules, d = diameter of pipe in inches.
L = length of pipe in yards.
H = head of water in feet.
G = gallons per minute.

These rules require the use of logarithms to work them easily.

The calculations used in " Practical Hydraulics," by Box, for ascertaining the friction in pipes, are for iron pipes. In practice it has been found that 2¾-inch (·0698 m.) rubber lined hose can be compared with 3-inch (·0782 m.) iron pipe (see Table on p. 103).

The obstruction also due to the flow of water by the restriction caused by badly designed couplings is very material, but this fact is not often taken into account when calculating the loss of head due to friction.

The correction that has to be made for all kinds of hose depends upon the degree of internal roughness which varies very much in hose of different makes.

The percentages due to the loss of pressure due to friction in various kinds of fire hose are set out in the Table on pp. 104 and 105.

The now general use of power-driven fire pumps makes available a higher initial pressure, and consequently a greater flow. This increased flow naturally entails a higher percentage loss of initial pressure due to friction, but with 100 or 120 lbs. on the square inch (6·8 to 8·2 atms.) at the outlet one can afford to lose more than when only 40 or 50 lbs. pressure (2·7 to 3·4 atms.) are available.

Mr. J. R. Freeman published some years ago in the United States, a work on " Experiments relating to the Hydraulics of Fire Streams." This was the result of long and costly experiments.

* See Appendix, under Mensuration.

TABLE OF THE HEAD OF WATER CONSUMED BY FRICTION WITH PIPES 1 YARD (0·9143 M.) LONG. The head in the 3-inch (0·0762 m.) iron pipes is calculated by the rules given in "Practical Hydraulics" by Box, and the head in the $2\frac{3}{4}$-inch (0·0698 m.) rubber lined hose from actual measurements.

Gallons per Minute.	3-inch Iron pipes.	$2\frac{3}{4}$-inch R.L. Hose.	Gallons per Minute.	3-inch Iron pipes.	$2\frac{3}{4}$-inch R.L. Hose.	Gallons per Minute.	3-inch Iron pipes.	$2\frac{3}{4}$-inch R.L. Hose.
1	·000016	·000017	200	·677	·686	480	3·90	3·95
2	·000067	·000068	210	·747	·753	490	4·06	4·11
3	·000152	·000154	220	·819	·829	500	4·23	4·28
4	·000271	·000274	230	·896	·906	520	4·58	4·63
5	·000423	·000428	240	·975	·987	540	4·93	4·99
6	·000609	·000616	250	1·058	1·070	560	5·31	5·37
7	·000830	·000839	260	1·145	1·158	580	5·69	5·76
8	·001084	·001096	270	1·234	1·249	600	6·09	6·17
9	·001372	·001387	280	1·328	1·343	620	6·51	6·58
10	·00169	·00171	290	1·424	1·440	640	6·93	7·02
20	·00677	·00685	300	1·524	1·542	660	7·37	7·46
30	·0152	·0154	310	1·627	1·647	680	7·83	7·92
40	·0271	·0274	320	1·734	1·754	700	8·30	8·39
50	·0423	·0428	330	1·844	1·865	720	8·78	8·88
50	·0609	·0617	340	1·958	1·980	740	9·28	9·38
70	·0830	·0839	350	2·075	2·098	760	9·78	9·89
80	·1084	·1096	360	2·196	2·220	780	10·30	10·42
90	·1372	·1387	370	2·336	2·345	800	10·84	10·96
100	·169	·173	380	2·446	2·473	820	11·39	11·52
110	·205	·207	390	2·576	2·605	840	11·95	12·09
120	·243	·247	400	2·710	2·740	860	12·52	12·67
130	·286	·289	410	2·847	2·879	880	13·11	13·26
140	·332	·336	420	2·988	3·021	900	13·72	13·87
150	·381	·385	430	3·13	3·17	920	14·38	14·50
160	·433	·438	440	3·27	3·32	940	14·96	15·13
170	·485	·495	450	3·43	3·47	960	15·61	15·79
180	·549	·555	460	3·58	3·62	980	16·26	16·45
190	·611	·618	470	3·74	3·78	1000	16·94	17·13

The book being out of print, Messrs. Shand, Mason & Co., reprinted a portion of the results, altering some of the descriptions and terms so as to make the matter more easily understood in England. The tables have also been recalculated to show *British imperial gallons*, 200 *of which are equal to* 240 *American gallons*.

By kind permission of Messrs. Shand, Mason & Co. the following extracts are given. It must always be remembered that every bend or rise in the ground adds considerably to the friction and thus reduces the pressures.

The distance and height to which a jet of water can be thrown by a pump are influenced by many conditions; the diameter of the jet, the form of the jet, the diameter of the hose, the smoothness of its interior, the mode of coupling, the position of the hose upon the ground, its freedom from sharp angles or nips, etc., all these affect the range most seriously; but the greatest impediment, and one which is always present, is the atmosphere.

These are all described in greater detail in the following pages.

Comparative Friction Loss in Various kinds of Fire Hose. The following comparison is made on the basis of 240 gallons per minute, flowing through hose in each case, which is about the quantity discharged by a $1\frac{1}{8}$-inch smooth nozzle under pressure of 40 lbs. (indicated) at base of play pipe.

Sample of Hose.	Diameter of Couplings.	Average Internal Diam. of Hose.	Mean Velocity in Hose feet per second.	Increase in Length under 50 lbs. average pressure.	Observed Loss of Pressure due Friction in each 100 feet of hose. Hose straightened and length measured under pressure lbs. per sq. in.	Percentage corresponding to diam. of Hose to be added or subtracted to give Friction which would have existed had diam. been exactly $2\frac{1}{2}$ inches.	Loss of Pressure due Friction in each 100 feet of Hose which this same Hose would have shown had diam. been exactly $2\frac{1}{2}$ inches.
Sample A.—$2\frac{1}{2}$-inch Solid Rubber Hose. A heavier hose than the next, weighing 25 per cent. more. The interior of this hose is free from ridges due threads of fabric, and was intended to be smooth as rubber could be made, being made on a highly polished steel mandrel.	Inches. 2·52	Inches. 2·65	13·96	¾%	10·0	Add 34%	13·4
Sample B.—$2\frac{1}{2}$-inch Solid Rubber Hose. The interior of this hose is free from ridges, due threads of fabric, and very smooth, but was made on a mandrel less highly polished than the last.	2·53	2·60	14·50	$1\frac{1}{2}$%	11·5	Add 22%	14·0
Sample C.—$2\frac{1}{2}$-inch Woven Cotton, Rubber Lined. A regular Fire Department Hose. Rubber lining is thick, and interstices between threads next to rubber lining filled with rubber, so that inner surface remains almost free of ridges under pressure. Hose of same grade as Sample D with addition of a jacket.	2·53	2·47	16·07	4%	15·0	Deduct 6%	14·1
Sample D.—$2\frac{1}{2}$-inch Woven Cotton, Rubber Lined. A medium-weight unjacketed hose. Rubber lining thicker than Sample K, and interstices between threads next to lining filled with rubber, so that inner surface remains almost free of ridges under pressure. Smoothness and character of lining apparently the same as Sample C.	2·47	2·49	15·81	5%	14·5	Deduct 2%	14·2
Sample E.—$2\frac{1}{2}$-inch Knit Cotton, Rubber Lined. A medium-weight hose. Inner surface medium smooth under pressure. Interstices between threads next lining well filled with rubber.	2·50	2·68	13·65	$3\frac{1}{2}$%	11·3	Add 42%	16·0
Sample F.—$2\frac{1}{2}$-inch Knit Cotton, Rubber Lined. A cheap, light-weight hose. Interior surface medium smooth.	2·50	2·50	15·69	$4\frac{1}{2}$%	16·8	0	16·8

Sample G.—2½-inch Knit Cotton, Rubber Lined. A regular Fire Department Hose. Said to be about the same grade as Sample I with a jacket added.	2·51	2·60	14·50	1¾%	13·9	Add 22%	17·0
Sample H.—2½-inch Knit Cotton, Rubber Lined. A rather cheap light-weight hose. Inside rather rough, due conformation of rubber lining to threads of fabric.	2·51	2·62	14·28	3%	14·4	Add 27%	18·3
Sample I.—2½-inch Knit Cotton, Rubber Lined. A somewhat heavier hose than the last, otherwise apparently the same.	2·51	2·69	13·55	2½%	13·5	Add 44%	19·4
Sample J.—2½-inch Leather Hose. A leather hose of excellent construction. Laps cut square.	2·50	2·80	12·51	2¼%	12·2	Add 76%	21·5
Sample K.—2½-inch Woven Cotton, Rubber Lined. A cheap hose with medium-thin rubber lining, which under pressure conformed to threads of fabric, thus making interior full of small ridges. Inferred from comparative appearance of roughness that most other makes of woven "Mill Hose" of same weight would, as now made, give similar friction, but they can be improved as illustrated in Sample D.	2·48	2·53	15·31	5%	24·1	Add 6%	25·5
Sample L.—2½-inch Unlined Linen Hose. This was an excellent piece of hose, and fairly represents friction loss in all ordinary unlined linen hose.	2·50	2·60	14·50	2½%	27·2	Add 22%	33·2
Sample M.—2-inch Woven Cotton, Rubber Lined Hose. Smoothness apparently same as Sample D, as judged by inspection of interior at ends of sample.	2·07	2·12	21·81	4½%	33·2	Deduct 56%	14·6
Sample N.—2½-inch Linen Hose with 2-inch Couplings. Fabric same as Sample L (Valve deducted from experiments with 200 gallons per minute flowing on this hose).	1·95	2·30	18·53	..	49·5	Deduct 34%	32·7
For comparison with above, it may be stated that the loss of pressure due friction in a common, clean, straight wrought-iron pipe coated with an asphaltum and 2½-inch diameter, discharging 240 gallons per minute, would be Computing and interpolating from experiments of Hamilton Smith, Jr., 15·7 lbs. per 100 feet; " " " " Henry Darcy, 14·0 " " } mean . . .							14·8

The correction given in the sixth column is based upon the well-known hydraulic rule, that for the same quantity flowing in long pipes of different diameters, but equal smoothness, the friction loss is inverse in proportion to the fifth power of the diameter.

The truth of this rule within the limits of the above experiments is demonstrated very well by a comparison of the last two experiments on M and N, with experiments on Samples C and L.

The figures in the seventh column give the true basis of judging of the relative excellence of a hose as regards smoothness of finish of interior.

Effect of Diameter of Hose upon Friction Loss.—To illustrate the effect of diameter upon hose of loss of pressure by friction, the following table is presented. This is computed by the well-established law that loss of pressure varies inversely as the fifth power of diameter.

For hose of the same smoothness, and with the same number of gallons per minute flowing, *the loss of pressure* due to friction per 100 feet of

3-inch	hose is	40 per cent. of that	in hose of	exactly	$2\frac{1}{2}$	inches	diameter.
$2\frac{7}{8}$-inch	,,	50 ,,	,,	,,	,,	,,	,,
$2\frac{3}{4}$-inch	,,	62 ,,	,,	,,	,,	,,	,,
$2\frac{5}{8}$-inch	,,	78 ,,	,,	,,	,,	,,	,,
$2\frac{3}{8}$-inch	,,	29 per cent. *more* than in		,,	,,	,,	
$2\frac{1}{4}$-inch	,,	70 ,,	,,	,,	,,	,,	
$2\frac{1}{8}$-inch	,,	twice as much as in		,,	,,	,,	
2-inch	,,	3·05 times	,,	,,	,,	,,	

Loss of Pressure due to Friction in different kinds of Hose.—There is a great difference in the loss due to friction in different kinds of hose, and basing his calculations upon very careful experiments, Mr. Freeman adopted for his tables (see pp. 110 to 115) the values as under, corresponding to three different kinds of hose, for pounds pressure lost between engine or hydrant and branch-pipe, per 100 feet of hose with 200 gallons per minute flowing.

For ordinary canvas hose $2\frac{1}{2}$-in. nominal diameter, .	30 lbs. per 100 feet.
For $2\frac{1}{2}$-in. nominal diameter lined hose, in which the rubber lining was rather thin, so that the inner surface conforming under the pressure of the water, to the threads of the canvas covering, became full of small ridges, ...	26 lbs. per 100 feet.
For a much heavier $2\frac{1}{2}$-in. nominal diameter hose, with thick rubber lining, the interstices between threads next to lining being well filled so that inner surface remained smooth under water pressure, ...	13 lbs. per 100 feet.

Values for grades of hose giving intermediate friction losses can be readily inserted. Mr. Freeman's exhaustive experiments included some made with best leather hose, which showed a friction loss of about one-sixth less than the second value (light rubber-lined hose) given above. Between the leather and the heavy rubber-lined hose, to which the third value is attached, came five varieties of rubber-lined hose, each showing slightly less friction loss than the preceding one, corresponding to the greater thickness of the rubber lining, and the better filling of the interstices between the threads of the woven fabric (see Table, pp. 110 to 115).

It is necessary to observe that the hose used by Mr. Freeman in his experiments, although known as $2\frac{1}{2}$-inch, in some instances varied rather considerably. Taking the three classes mentioned in the tables reproduced on pp. 110 to 115, we gather that the unlined canvas and best lined canvas hose were both somewhat larger than $2\frac{1}{2}$ inches in diameter—in fact, nearer $2\frac{5}{8}$ inches, whereas the inferior lined hose was, if anything, slightly *less* than its nominal diameter.

It should be added that while the friction loss is found to be much greater for canvas hose than for the rubber-lined hose from which the best results were obtained, the extreme lightness, compactness, durability, and inexpensiveness of the former, render it far more suitable for most fire brigade purposes than any other. Canvas hose is from one-third to one fourth the weight of the smooth rubber-lined hose above referred to.

Variations in Size of Couplings—Effect upon Friction Loss.—With the exception of the 25-foot piece ordinarily used next the hydrant, all hose experimented upon was in the ordinary 50-feet commercial lengths, 2½-inch diameter hose, and all were fitted with ordinary expanded ring couplings, giving a clear waterway of 2½ inches. Care was taken in all cases that the hole in the elastic washer used for packing the joint was of full size of bore of coupling.

A few experiments were made to see what extra friction loss would be caused by couplings of 2¼-inch bore on 2½-inch hose. These experiments were made by taking a line of 2½-inch hose about 300 feet in length, having full-size 2½-inch couplings, and after having carefully determined the loss of pressure in its length for certain rates of flow, water was shut off, the joints between the six 50-feet sections of hose uncoupled, and bushings, consisting of tubes 4½ inches long with 2¼-inch diameter of waterway and square ends, were inserted at each of the five points. The joints were then coupled up again, and the loss of pressure determined for the same rate of flow as before.

Two entirely independent sets of experiments were made with different kinds of hose, and from the experiments it was deduced that with 200 gallons per minute flowing, the effect of such a square-shouldered reduction of waterway at hose coupling from 2½ to 2¼ inches would be to cause a loss of 0·25 lb. at each bushing, or 0·50 lb. additional loss per 100 feet of hose.

If the up-stream end or entrance of bushing had been rounded, and discharging end tapered out to full diameter, the loss due to the reduction of area at coupling could have been made much smaller, or probably less than half the above amount.

Effect of Curves upon Pressure in lines of Hose.—Curves of any radius possible, without cramping or kinking the hose, were found to retard the flow but little. The natural ordinary sinuosity of a line of ordinary fire hose was found to increase friction only about 5 or 6 per cent., and some rather curious results have been obtained, indicating that within certain limits the loss due to a given amount of curvature was greater for a large radius than for a small. Perhaps the reason for this is that the arc was longer, and thus there was a greater length of pipe in which the current was disturbed. For the standard 200-gallon stream ordinary sinuosity (without cramping or kinking) will add about 1 lb. to the loss in the hose per 100 feet.

The Influence of Wind upon Vertical and Horizontal Streams.—Mr. Freeman says he is disposed to regard with suspicion the high accuracy of any experiments with high jets, which are not described with the fullest details as to stillness of air. He was surprised at the extreme sensitiveness of heights of jets at 40 lbs. or more pressure to even very faint wind. On three or four different days a slight breeze sprang up just as experiments on jets either vertical or at 75 or 60 degrees elevation were being commenced, and

it was found that even a moderate summer afternoon zephyr would cut down the height of the extreme drops by fully 10 per cent. A "moderate to fresh" breeze blowing at the rate of 8 to 12 miles an hour, reduced the height of the extreme drops of a stream from 82 to 67 feet. This jet was of $1\frac{1}{4}$ inches diameter, under 50 lbs. pressure, and set at an angle of 60 degrees. On another occasion, when experimenting on the maximum horizontal distance that a jet could be thrown, it was found that a gentle breeze, apparently of about approximately 4 miles per hour, blowing in direction opposite to jet, reduced the distance attained by the extreme drops from 125 to 100 feet.

The Advantage of Breeching Pieces for Long Lines of Hose.—It is a matter of great regret to see how seldom a breeching piece is used to connect two lines of hose from one steamer into a single line, at a point 50 feet or 100 feet back from the nozzle, in cases where the distance from the steamer to the seat of the fire is great. When we thus carry the water through two lines of hose, instead of through a single line of hose, *the velocity of the water is of course but half as great* in each of the two lines. The result of this is that the *loss of pressure is only one-fourth* as much as in the case of a single line, and if the steamer stands 1,000 feet away from the breeching, we have by the double line of hose practically reduced this distance to 250 feet.

At some fires, two steam fire engines are to be seen labouring heavily to do what one steamer and a double line of hose could have done much better. We refer to one steamer pumping to a second steamer, and the latter pumping on to the fire. There are many good practical firemen who will say it is contrary to common sense to claim that this breeching and the double line of hose will do more work than the second steamer, but let them try the experiment and see. We can also prove it by a simple little compilation.

Suppose the fire to be 1,800 feet away from the nearest good service of water, and to require a good 1-inch stream to a height of about 60 feet. For this we must have a delivery of 145 gallons per minute.

First case—two steamers and a single line of hose.—It may be calculated from the table on p. 112 (deducting pressure at nozzle) taken in conjunction with the observations on p. 106, that to deliver the 145 gallons per minute required, through 1,000 feet of $2\frac{3}{4}$-inch canvas hose, into the suction of the second steamer, will need approximately a water pressure of 128 lbs. at the first steamer. The second steamer must show a water pressure of about 137 lbs. to play this good 1-inch stream through 800 feet of $2\frac{3}{4}$-inch canvas hose, and get the necessary 35 lbs. at the branch-pipe to deliver to the height named. We thus require the work of two steamers to get the desired jet.

Second case—one steamer and double line of hose.—For the same situation take a double line of $2\frac{3}{4}$-inch hose, 1,750 feet long, bring the two together by a breeching, and to this attach a single 50-feet length of hose leading to the nozzle. To give our stream pressure of 35 lbs. at the branch-pipe, we must, 50 feet back from the nozzle, at the breeching, have a pressure of 42 lbs., and thence, for the 1,750 feet back to the steamer, the 72 gallons per minute flowing in each line will cause only $13 \div 4 = 3\frac{1}{4}$ lbs. friction loss per 100 feet, or 57 lbs. in all, which added to the 42 lbs., gives 99 lbs. at the steamer.

In the first case with two steamers, one playing into the other, the average steamer pressure was 132½ lbs. The entire labour of one steamer, and a good portion of the work of the other, was absorbed in useless friction, which is wholly avoided by the extra line of hose. In other words, the simple expedient of dividing the stream into two parts, and uniting them again by a breeching, a convenient distance back from the nozzle, is more efficient than an extra steamer, and sets the second steamer free for useful work elsewhere.

Explanation of Definitions in Tables.—It will be noted that in the first column of the table the pressure is called "indicated pressure," meaning by this that it was the pressure which the gauge attached to the proper piezometer on a hose or pipe 2½ inches in diameter, would indicate while the stream was flowing. Nearly all, if not all, other authors have based their tables upon the hydro-static pressure, which of course equals the indicated pressure plus an allowance for mean velocity of current past piezometer. Thus, for instance, the indicated pressure of 50 lbs. given in the bold type of the first column of following table, for 1⅛-inch smooth nozzle, corresponds to an effective pressure of 52·1 lbs., as given by Ellis, Weston, or Box.

The third and fifth columns of the tables give the maximum limit of height and distance as a "good effective fire stream." For very favourable conditions with still air, the stream would be powerful enough to do very fair execution at a considerably greater distance, but in fixing this limit as a good effective stream, it was intended that the figure given should be low enough, so that it could be safely relied upon as a good stiff stream out to this point under almost any practical conditions—such, for instance, as when a fresh breeze was blowing.

Mr. Freeman classes as "good" a stream which at the limit named would enter through a window and just strike the ceiling of the room with force enough to spatter well, and which at the limit named has not lost its continuity and solidity by dividing into a mere shower of spray.

In fixing the extreme horizontal distance reached by a jet as a good effective fire stream, the jet itself is not supposed to be horizontal, but inclined upwards at an ordinary working angle of about 30 to 45 degrees. In other words, with say 1⅛-inch nozzle, and with pressure at nozzle of 40 lbs., the stream would reach in excellent condition a third storey window of a building 59 feet distant from the end of the nozzle.

As to number of gallons per minute discharged, this quantity as given in the table is probably exactly correct within less than a single gallon for the exact size and pressure stated; with any ordinary varieties of smooth form of taper or finish of nozzle or branch pipe, the variation in form or finish was found to lead to no error of practical importance; but it must be borne in mind that a difference of $\frac{1}{100}$ of an inch in diameter of orifice of nozzle makes a little more than 2 per cent. difference in its discharge. In computing this part of the table the value assumed for coefficient discharge was 0·974.

The values for hydrant pressures given in the tables include an allowance for the ordinary crookedness of lines of hose. There is also included an allowance for the small loss of pressure in head of hydrant where water enters hose. This in computing table was assumed to be double the

Table of Pressure required at Hydrant or Steamer using 2½-inch Hose, nominal diameter (see note, page 106) to give certain pressures at Nozzle, with number of gallons discharged, and height of jet produced with the various pressures through ¾-inch Nozzle.

Indicated pressure by Gauge at Base of Branch-pipe.	Effective or Static Pressure at Base of Branch-pipe.	Height of Jet.		Horizontal distance reached by Jet.		Gallons per minute discharged (English Imperial)	Pressure required at Hydrant or Steamer (while stream is flowing) to maintain pressure at base of branch-pipe, shown in first column, through various lengths of hose.								
		Average of Highest Drops, Vertical Jet, in still air.	Maximum Limit of Height as "good effective fire stream," with moderate wind see p 107	Average Extreme Drops at level of Nozzle in still air.	Maximum Limit of Distance as "good effective fire stream," with moderate wind see p 107		50-ft Ordinary Canvas Hose	100-ft. Ordinary Canvas Hose.	200-ft Ordinary Canvas Hose.	300-ft Ordinary Canvas Hose	400-ft Ordinary Canvas Hose	500-ft. Ordinary Canvas Hose.	600-ft. Ordinary Canvas Hose.	800-ft. Ordinary Canvas Hose.	1 000-ft. Ordinary Canvas Hose.
lb.	lb.	ft	ft	ft	ft	gals	lb	lb	lb	lb	lb	lb	lb	lb	lb
5	5	10	...	18	...	31	5	6	6	7	8	9	9	11	12
10	10·1	20	17	36	19	43	11	12	13	14	16	17	19	21	24
15	15·1	30	25	54	24	53	16	17	19	22	24	26	28	32	36
20	20·2	40	33	72	29	61	22	23	26	29	32	34	37	43	48
25	25·2	50	41	86	33	68	27	29	32	36	39	43	46	53	61
30	30·2	59	48	96	37	75	33	35	39	43	47	52	56	64	73
35	35·3	69	55	105	41	81	38	40	45	50	55	60	65	75	85
40	40·3	78	60	112	44	87	43	46	52	58	63	69	74	86	97
45	45·4	86	64	119	47	92	49	52	58	65	71	77	84	96	109
50	50·4	93	67	125	50	97	54	58	65	72	79	86	93	107	121
55	55·5	99	70	131	52	102	60	64	71	79	87	95	102	118	133
60	60·5	104	72	136	54	106	65	69	78	86	95	103	112	128	145
65	65·5	109	74	141	56	110	71	75	84	93	103	112	121	139	157
70	70·6	114	76	145	58	114	76	81	91	101	110	120	130	150	169
75	75·6	119	78	149	60	118	81	87	97	108	118	129	139	160	182
80	80·7	123	79	153	62	122	87	93	104	115	126	138	149	171	194
85	85·7	126	80	157	64	126	92	98	110	122	134	146	158	182	206
90	90·7	129	81	161	65	130	98	104	117	129	142	154	167	193	218
95	95·8	132	82	164	66	133	103	110	123	137	150	163	177	203	230
100	100·8	134	83	167	68	137	109	116	130	144	158	172	186	214	242

Note.—With hose of exactly 2¼ inches diameter, the loss by friction (*i.e.*, the difference between the pressure at hydrant or engine and indicated pressure at base of branch-pipe) would be 38 per cent. less than in hose of 2½ inch exact diameter. With 2⅜-inch hose the loss would be approximately 22 per cent. less.

TABLE OF PRESSURE REQUIRED AT HYDRANT OR STEAMER USING 2½-INCH HOSE, nominal diameter (see note, page 106), to give certain pressures at Nozzle, with number of gallons discharged, and height of jet produced with the various pressures through ⅞-inch Nozzle.

Indicated pressure by Gauge at Base of Branch-pipe.	Effective or Static Pressure at Base of Branch-pipe.	Height of Jet.		Horizontal distance reached by Jet.		Gallons per minute discharged (English Imperial).	Pressure required at Hydrant or Steamer (while stream is flowing) to maintain pressure at base of branch-pipe, shown in first column, through various lengths of hose.								
		Average of Highest Drops, Vertical Jet, in still air.	Maximum Limit of Height as "good effective fire stream," with moderate wind, see p. 107.	Average Extreme Drops at level of Nozzle in still air	Maximum Limit of Distance as "good effective fire stream," with moderate wind see p 107		50-ft. Ordinary Canvas Hose.	100-ft. Ordinary Canvas Hose.	200-ft. Ordinary Canvas Hose.	300-ft. Ordinary Canvas Hose	400-ft. Ordinary Canvas Hose.	500-ft Ordinary Canvas Hose.	600-ft. Ordinary Canvas Hose.	800-ft. Ordinary Canvas Hose.	1,000-ft. Ordinary Canvas Hose.
lb.	lb.	ft.	ft.	ft.	ft.	gals	lb.	lb	lb.	lb	lb.	lb	lb.	lb.	lb.
5	5·1	11	...	18	...	42	6	6	8	9	10	12	13	16	18
10	10·2	21	18	37	21	59	12	13	16	18	21	23	26	31	37
15	15·2	31	26	56	27	72	17	19	23	27	31	35	39	47	55
20	20·3	41	34	74	33	83	23	26	31	36	42	47	52	63	73
25	25·4	51	42	90	38	93	29	32	39	45	52	59	65	78	91
30	30·5	61	49	103	42	102	35	39	47	54	62	70	78	94	110
35	35·5	71	56	114	46	111	41	45	54	64	73	82	91	109	128
40	40·6	81	62	124	49	118	46	52	62	73	83	94	104	125	146
45	45·7	89	67	132	52	125	52	58	70	82	94	105	117	141	164
50	50·8	97	71	140	55	132	58	65	78	91	104	117	130	156	183
55	55·8	105	74	147	58	138	64	71	85	100	114	129	143	172	201
60	60·9	112	77	153	61	145	70	78	93	109	125	140	156	188	219
65	66·0	118	79	158	64	151	75	84	101	118	135	152	169	203	237
70	71·0	123	81	163	66	157	81	90	109	127	145	164	182	219	255
75	76·1	128	83	168	68	162	87	97	117	136	156	175	195	234	...
80	81·2	132	85	172	70	167	93	103	124	145	166	187	208	250	...
85	86·3	136	87	176	72	172	99	110	132	154	177	199	221	...	...
90	91·3	139	88	180	74	177	104	116	140	163	187	211	234	...	...
95	96·4	142	89	183	75	182	110	123	148	173	197	222	247	...	...
100	101·5	144	90	186	76	187	116	129	155	182	208	234	260	...	...

Note.—With hose of exactly 2¾ inches diameter, the loss by friction (*i.e.*, the difference between the pressure at hydrant or engine and indicated pressure at base of branch-pipe) would be 38 per cent. less than in hose of 2½ inch exact diameter. With 2⅝-inch hose the loss would be approximately 22 per cent. less.

Table of Pressure required at Hydrant or Steamer using $2\frac{1}{2}$-inch Hose, nominal diameter (see note, page 106), to give certain pressures at Nozzle, with number of gallons discharged, and height of jet produced with the various pressures through 1-inch Nozzle.

Indicated pressure by Gauge at Base of Branch-pipe.	Effective or Static Pressure at Base of Branch-pipe.	Height of Jet. Average of Highest Drops. Vertical Jet, in still air.	Height of Jet. Maximum Limit of Height as "good effective fire stream," with moderate wind see p. 107.	Horizontal distance reached by Jet. Average Extreme Drops at level of Nozzle in still air.	Horizontal distance reached by Jet. Maximum Limit of Distance as "good effective fire stream," with moderate wind see p. 107	Gallons per minute discharged (English Imperial).	Pressure required at Hydrant or Steamer (while stream is flowing) to maintain pressure at base of branch-pipe, shown in first column, through various lengths of hose. 50-ft. Ordinary Canvas Hose.	100-ft. Ordinary Canvas Hose.	200-ft. Ordinary Canvas Hose.	300-ft. Ordinary Canvas Hose.	400-ft. Ordinary Canvas Hose.	500-ft. Ordinary Canvas Hose.	600-ft. Ordinary Canvas Hose.	800-ft. Ordinary Canvas Hose.	1,000-ft. Ordinary Canvas Hose.
lb.	lb.	ft.	ft.	ft.	ft.	gals.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
5	5·1	10	...	17	...	55	6	8	10	12	14	17	19	23	28
10	10·3	21	18	38	21	77	13	15	20	24	29	33	38	47	56
15	15·4	32	26	58	30	95	19	23	29	36	43	50	57	70	84
20	20·5	43	35	77	37	110	26	30	39	48	57	66	75	93	111
25	25·6	53	43	94	42	122	32	38	49	60	71	83	94	117	139
30	30·8	63	51	109	47	134	38	45	59	72	86	99	113	140	167
35	35·9	73	58	122	51	145	45	53	68	84	100	116	132	163	195
40	41·0	83	64	133	55	155	51	60	78	96	114	132	151	187	223
45	46·2	92	69	143	58	165	57	68	88	108	129	149	169	210	251
50	51·3	101	73	152	61	173	64	75	98	120	143	166	188	233	...
55	56·4	109	76	160	64	182	70	83	108	132	157	182	207	...	...
60	61·5	117	79	167	67	190	77	90	117	144	171	199	226	...	...
65	66·7	124	82	173	70	197	83	98	127	156	186	215	244	...	...
70	71·8	130	85	179	72	205	89	105	137	168	200	232	...	...	...
75	76·9	135	87	184	74	212	96	113	147	181	214	248	...	...	...
80	82·1	140	89	189	76	219	102	120	156	193	229	...	...	...	...
85	87·2	144	91	193	78	228	109	128	166	205	243	...	...	...	...
90	92·3	147	92	197	80	232	115	135	176	217	257	...	...	...	...
95	97·4	150	94	201	82	239	121	143	186	229	...	...	...	...	...
100	102·6	152	96	205	83	246	128	150	195	241	...	...	...	...	...

Note.—With hose of exactly $2\frac{3}{4}$ inches diameter, the loss by friction (*i.e.*, the difference between the pressure at hydrant or engine and indicated pressure at base of branch-pipe) would be 38 per cent. less than in hose of $2\frac{1}{2}$ inch exact diameter. With $2\frac{5}{8}$-inch hose the loss would be approximately 22 per cent. less.

Table of Pressure required at Hydrant or Steamer using 2½-inch Hose, nominal diameter (see note, page 106), to give certain pressures at Nozzle, with number of gallons discharged, and height of jet produced with the various pressures through 1⅛-inch Nozzle.

Indicated pressure by Gauge at Base of Branch-pipe.	Effective or Static Pressure at Base of Branch-pipe.	Height of Jet.		Horizontal distance reached by Jet.		Gallons per minute discharged (English Imperial)	Pressure required at Hydrant or Steamer (while stream is flowing) to maintain pressure at base of branch-pipe shown in first column through various lengths of hose.								
		Average of Highest Drops, Vertical Jet, in still air.	Maximum Limit of Height as "good effective fire stream," with moderate wind, see p. 107.	Average Extreme Drops at level of Nozzle in still air.	Maximum Limit of Distance as "good effective fire stream," with moderate wind see p 107		50-ft Ordinary Canvas Hose.	100-ft. Ordinary Canvas Hose.	200-ft Ordinary Canvas Hose.	300-ft Ordinary Canvas Hose.	400-ft Ordinary Canvas Hose.	500-ft Ordinary Canvas Hose.	600-ft Ordinary Canvas Hose	800-ft Ordinary Canvas Hose	1 000-ft Ordinary Canvas Hose.
lb.	lb.	ft.	ft.	ft.	ft.	gals	lb	lb	lb	lb	lb	lb	lb	lb	lb.
5	5·2	11	...	19	...	70	7	9	13	16	20	24	28	35	42
10	10·4	22	18	39	22	99	15	18	26	33	40	48	55	70	84
15	15 6	32	27	59	31	122	22	27	38	49	60	71	82	105	127
20	20·8	43	36	80	38	140	29	36	51	66	80	95	110	139	168
25	26·0	54	44	99	44	157	36	45	64	82	101	119	137	174	211
30	31·2	64	52	115	50	172	44	55	77	99	121	143	165	209	253
35	36·4	74	59	130	54	185	51	64	89	115	141	166	192	243	...
40	41·7	84	65	142	59	198	58	73	102	131	161	190	220	278	...
45	46·9	94	70	152	63	210	65	82	115	148	181	214	247	...	...
50	52·1	104	75	162	66	222	72	91	128	164	201	238	274	...	...
55	57·3	113	80	170	69	232	80	100	140	181	221	262	...	...	...
60	62·5	122	83	178	72	242	87	109	153	197	241	...	...	...	...
65	67·7	130	86	185	75	252	94	118	166	214	261	...	...	...	...
70	72·9	136	88	191	77	262	101	127	179	230	...	...	...	...	...
75	78·1	142	90	197	79	271	109	136	191	246	...	...	...	...	...
80	83·3	146	92	203	81	280	116	145	204	263	...	...	...	..	...
85	88·5	150	94	209	83	288	123	154	217	...	...	...	...	...	...
90	93·7	153	96	214	85	297	130	164	230	...	...	...	...	...	...
95	98·9	156	98	219	87	305	138	173	242	...	...	...	...	...	...
100	104·1	158	99	224	89	313	145	182	255	...	...	...	...	...	...

Note.—With hose of exactly 2½ inches diameter, the loss by friction (*i.e.*, the difference between the pressure at hydrant or engine and indicated pressure at base of branch-pipe) would be 38 per cent less than in hose of 2½ inch exact diameter. With 2⅝-inch hose the loss would be approximately 22 per cent. less.

TABLE OF PRESSURE REQUIRED AT HYDRANT OR STEAMER USING $2\frac{1}{2}$-INCH HOSE, nominal diameter (see note, page 106), to give certain pressures at nozzle, with number of gallons discharged, and height of jet produced ~~with the various~~ pressures ~~through~~ $1\frac{1}{4}$-inch Nozzle.

Indicated pressure by Gauge at Base of Branch-pipe.	Effective or Static Pressure at Base of Branch-pipe.	Height of Jet. Average of Highest Drops, Vertical Jet, in still air.	Height of Jet. Maximum Limit of Height, as "good effective fire stream," with moderate wind, see p. 107.	Horizontal distance reached by Jet. Average Extreme Drops at level of Nozzle in still air.	Horizontal distance reached by Jet. Maximum Limit of Distance as "good effective fire stream," with moderate wind, see p. 107.	Gallons per minute discharged (English Imperial).	Pressure required at Hydrant or Steamer (while stream is flowing) to maintain pressure at base of branch-pipe, shown in first column, through various lengths of hose. 50-ft. Ordinary Canvas Hose.	100-ft. Ordinary Canvas Hose.	200-ft. Ordinary Canvas Hose.	300-ft. Ordinary Canvas Hose.	400-ft. Ordinary Canvas Hose.	500-ft. Ordinary Canvas Hose.	600-ft. Ordinary Canvas Hose.	800-ft. Ordinary Canvas Hose.	1,000-ft. Ordinary Canvas Hose.
lb.	lb.	ft.	ft.	ft.	ft.	gals.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
5	5·3	11	...	19	...	87	8	11	17	23	28	34	40	51	63
10	10·6	22	19	40	22	123	17	23	34	46	57	68	80	103	125
15	15·9	33	28	62	32	151	25	34	51	68	85	102	120	154	188
20	21·2	44	37	83	40	174	34	45	68	91	114	137	159	205	251
25	26·5	55	46	103	47	195	42	57	85	114	142	171	199	256	...
30	31·8	66	53	119	54	213	51	68	102	136	171	205	239	...	...
35	37·1	76	60	134	59	231	59	79	119	159	199	239	279	...	...
40	42·4	86	67	148	63	247	68	91	136	182	227	273	...	...	...
45	47·8	97	72	159	67	262	76	102	153	205	256	...	...	...	...
50	53·1	107	77	169	70	276	85	113	170	227	...	...	...	...	...
55	58·4	117	81	178	73	289	93	124	187	249	...	...	...	...	...
60	63·7	126	85	186	76	302	102	136	204	...	...	...	...	...	...
65	69·0	133	88	193	79	314	110	147	221	...	...	...	...	...	...
70	74·3	140	91	200	81	327	118	158	238	...	...	...	...	...	...
75	79·6	145	93	207	83	337	127	170	255	...	...	...	...	...	...
80	84·9	150	95	213	85	349	135	181	...	...	...	...	...	...	...
85	90·2	154	97	219	88	360	144	192	...	...	...	...	...	...	...
90	95·5	157	99	225	90	370	152	204	...	...	...	...	...	...	...
95	100·8	159	100	231	92	380	161	215	...	...	...	...	...	...	...
100	106·1	161	101	236	93	390	169	226	...	...	...	...	...	...	...

Note.—With hose of exactly $2\frac{3}{4}$ inches diameter, the loss by friction (*i.e.*, the difference between the pressure at hydrant or engine and indicated pressure at base of branch-pipe) would be 38 per cent. less than in hose of $2\frac{1}{2}$ inch exact diameter. With $2\frac{5}{8}$-inch hose the loss would be approximately 22 per cent. less.

Table of Pressure required at Hydrant or Steamer using 2½-inch Hose, nominal diameter (see note, page 106), to give certain pressures at Nozzle, with number of gallons discharged, and height of jet produced with the various pressures through 1⅜-inch Nozzle.

Indicated pressure by Gauge at Base of Branch-pipe.	Effective or Static Pressure at Base of Branch-pipe.	Height of Jet: Average of Highest Drops, Vertical Jet, in still air.	Height of Jet: Maximum Limit of Height as "good effective fire stream," with moderate wind, see p. 107.	Horizontal distance reached by Jet: Average Extreme Drops at level of Nozzle in still air.	Horizontal distance reached by Jet: Maximum Limit of Distance as "good effective fire stream," with moderate wind, see p. 107.	Gallons per minute discharged (English Imperial).	Pressure required at Hydrant or Steamer (while stream is flowing) to maintain pressure at base of branch-pipe shown in first column, through various lengths of hose: 50-ft. Ordinary Canvas Hose	100-ft. Ordinary Canvas Hose.	200-ft. Ordinary Canvas Hose.	300-ft. Ordinary Canvas Hose.	400-ft. Ordinary Canvas Hose.	500-ft. Ordinary Canvas Hose.	600-ft. Ordinary Canvas Hose.	800-ft. Ordinary Canvas Hose.	1,000-ft. Ordinary Canvas Hose.
lb.	lb.	ft.	ft.	ft.	ft.	gals.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
5	5·5	12	...	19	...	**107**	10	15	23	32	40	49	57	74	92
10	10·9	23	20	41	23	**152**	20	29	46	63	81	98	115	149	184
15	16·4	34	29	63	33	**185**	31	44	69	95	121	147	172	224	275
20	21·8	45	38	85	42	**214**	41	58	92	127	161	195	230	299	...
25	27·3	56	47	106	49	**239**	51	73	115	158	201	244	287	...	...
30	32·7	67	55	123	56	**262**	61	87	139	190	242	293	...	...	...
35	38·2	78	62	138	62	**283**	71	102	162	222	282	...	...	...	...
40	43·7	89	69	152	66	**302**	82	116	185	253	...	...	...	...	...
45	49·1	100	74	164	70	**321**	92	131	208	...	...	...	...	...	...
50	54·6	111	79	175	73	**338**	102	145	231	...	...	...	...	...	...
55	60·0	121	83	184	76	**355**	112	160	254	...	...	...	...	...	...
60	65·5	131	87	192	79	**371**	122	174	...	...	...	...	...	...	...
65	70·9	138	90	200	82	**386**	133	189	...	...	...	...	...	...	...
70	76·4	144	92	207	84	**400**	143	203	...	...	...	...	...	...	...
75	81·9	149	95	214	86	**414**	153	218	...	...	...	...	...	...	...
80	87·3	154	97	220	88	**428**	163	232	...	...	...	...	...	...	...
85	92·8	158	99	226	90	**441**	174	247	...	...	...	...	...	...	...
90	98·2	161	100	232	92	**454**	184	261	...	...	...	...	...	...	...
95	103·7	163	101	238	94	**467**	194	...	...	...	...	...	...	...	...
100	109·1	164	103	243	96	**478**	204	..	...	...	...	...	...	...	...

Note.—With hose of exactly 2¾ inches diameter, the loss by friction (*i.e.*, the difference between the pressure at hydrant or engine and indicated pressure at base of branch pipe) would be 38 per cent. less than in hose of 2½ inch exact diameter. With 2⅝-inch hose the loss would be approximately 22 per cent. less.

theoretical head necessary to produce this velocity in a 2½-inch coupling, this being the ratio actually found by the writer in a series of experiments.

For taking the pressures a gauge was attached to base of branch-pipe. For all practical purposes the pressures given may be taken to be the same at end of nozzle, the pressure absorbed by friction within the 2 or 3 feet from base of branch to nozzle being very small.

The Care of Canvas Hose.—In using Canvas Hose care must be taken not to drag it along the ground or over rough-edged walls, as this tends to injure the fabric.

After use, the hose should be uncoupled and drained, as far as practicable, by lifting one end of the length, moving forward, and gradually passing the whole over the shoulder. This is much preferable to the common method of forcing the water out by walking along the hose as it lies upon the ground.

When returned to the station, Canvas Hose should (if dirty) be promptly cleansed with clear water and then suspended in the hose tower until dry, as, if hose be put away damp, it is liable to rot. Where artificial heat is used for drying, it should not exceed say 100 degrees Fahr. The couplings should be kept clear of grit, and the washers in the female end of screw couplings occasionally moistened with oil.

When dried, or immediately after a dry drill, the hose, if it is to be coiled, should be rolled up carefully and evenly, and secured with the strap and buckle attached. The practice of stamping upon a coil of hose to correct slovenly work in rolling up cannot be too strongly condemned.

If flaked in hose-cart, or carried on a reel, the hose should be re-coupled and folded into the box, or reeled neatly, to facilitate its rapid withdrawal when required for use.

The hose should be kept in a well-ventilated place, free from damp.

Very long experience in connection with canvas hose shows that weakness first exhibits itself along the folds of the flattened material, this being due to the constant outside friction upon the same spot, and anything that will reduce this wear, tends to lengthen the life of the hose.

Part II—FIRES.

CHAPTER IV.

CAUSES OF FIRES—DANGEROUS TRADES.

It can safely be said that carelessness lies at the root of all so-called "causes" of fires.

This may seem a strong statement, but if it be thoroughly and impartially investigated, there is no doubt but that it will be found to be correct.

It might be argued, for instance, that such physico-chemical processes as pyrophorism and spontaneous combustion, or the more subtle selective action which certain metal powders exercise on the oxygen contained in atmospheric moisture cannot be attributed to carelessness.

The answer to this and to all similar arguments is that so much is known of these processes and so many warnings have been given of their dangerous possibilities by earnest, far-seeing men who, being convinced by their own experience, have never wearied of their uphill and seldom appreciated work of fire prevention propaganda, that had others, having profited by the experience of such men, allowed these processes of deterioration and destruction by fire to continue in buildings entrusted to their care, they would be most certainly guilty of gross carelessness.

When a fire takes place in a German town, the owner of the premises affected has to demonstrate satisfactorily to the Fire Police authorities that he is innocent of any contributory carelessness, or of inobservance of any of the many useful fire prevention regulations. Otherwise he will find that to his already severe loss must be added a substantial fine, and that he is also liable for compensation to his neighbours.

There is no doubt that procedure such as this tends to make the owner exercise more care in the safeguarding of his property against fire.

In countries where such legislation is in force, it has been found that the fire loss per head of the population is considerably less than elsewhere.

Underneath this single heading of "Carelessness" may be grouped various sub-headings, each denoting one of the agents through which carelessness brings about its results. There are so many of these that it is only possible to deal with some of the more prominent, which have been arranged more or less in the order in which they are most common.

1. Matches.
2. Tobacco and smoking.
3. Defective flues and fireplaces.
4. Candles.
5. Oil lamps.
6. Gas.
7. Electricity.

8. Petrol, etc.
9. Celluloid.
10. Spontaneous combustion.
11. Pyrophoric action.
12. Dust explosion.
13. Rodents.
14. Night watchmen.
15. Overheating of bearings, etc.
16. Static electricity generated in industrial processes.
17. Workman employed on repairs.
18. Lightning.
19. Storage.
20. Rays of the sun.
21. Incendiarism.

(1) **Matches.**—Directly or indirectly, matches are a very prolific cause of fires, commencing their incendiary career during manufacture and continuing it during storage and transport, till it is finally terminated by its destruction through use or mis-use.

Some of the ways in which danger may be caused are enumerated here.

If a match is carelessly made, the head, when struck, flies off and lies perhaps in some hidden corner before the process of ignition has fully developed. Whilst lying unseen the tiny flames burst out, and ignite other objects in their turn. (For particulars of the manufacture of matches, see p. 44.)

Another danger is the heat which is stored in the apparently extinguished head of many varieties of match, and the prolonged incandescence of the stick. Children almost always love to play with matches, and how often older people who should know better fling matches away before they are properly extinguished.

It may be they are thrown into a waste-paper basket, a desk full of papers; or an article of furniture, a hearthrug or curtain, or perhaps a pile of rubbish beneath cellar gratings receives the still burning end, or it may be placed in the pocket of a coat hanging up where fire can lurk and grow, but it is usual that somewhere close by exists the material for carrying on the burning process, till a larger fire results.

Again, how frequently an unstruck match is dropped without the owner taking the trouble to pick it up. Many varieties of match, when dry, will ignite with the pressure of the foot or other friction, and when wet may adhere to the underside of the shoe and so be transported to some spot where it becomes a danger. Once there, the rays of the sun—a little extra heat—or even a mouse nibbling at it, may cause its ignition.

Again, " ordinary " matches, and some of the so-called " safety " matches, re-unite in the head itself all the chemicals necessary to ignition and combustion. The mere dropping of a box or packet of " ordinary " (not safety) matches from a shelf to the floor is frequently sufficient to cause ignition. The violent shocks given to matches during transport are a cause of trouble. They should be treated with the same care as detonators.

Another source of danger is furnished by the box in which safety matches are sold, and, as already mentioned, if throat lozenges, composed of chlorate

of potash, are placed in the same pocket as the match box, all the elements of a good fire are present. If one of these lozenges be rubbed gently on the striking strip of the box, flames will result, as the friction will warm up the red phosphorus and cause it to combine with the chlorate of potash, which is an oxygen carrier.

An extraordinary case occurred in which a box of lucifer matches had been placed behind an American clock upon a mantelshelf. The key-drop on the back of the clock during its slow revolutions, had managed to pinch in and hold the matches so tightly between itself and the shelf that the continual pressure and friction on the heads resulted in their ignition, and the flame soon extended to the whole contents of the box and the other articles near.

These few examples will tend to show the great possibilities of the match as an agent of destruction by fire. Similarly in all other cases dealt with, it will only be possible to draw attention to a few examples of how fires may be caused by each. No doubt many more will occur to the mind of the reader.

(2) **Tobacco and Smoking.**—This sub-heading stands, of course, in very intimate relation to the last, and has many parallel examples—as, for instance, the burning cigarette end carelessly laid down or thrown away, or, the pipe dottle tapped out and left to smoulder where it can be a source of danger.

Then there is the half-smoked pipe thrust away into the jacket pocket, the burning shreds of tobacco which fall from it when newly charged, and the disobedient smoker, who causes many fires.

(3) **Defective Flues and Fireplaces.**—Only some forty years ago it was a common practice in building to construct hearths by covering the space between the trimmer joists and the wall with rough boarding upon which a thin layer of concrete was laid to act as a bed for the hearth stone. The fire grates in use were of the old pattern with the grating some 12 inches above the floor line, and as these fireplaces were mostly in bedrooms, they were seldom used; nevertheless, on the occasions on which they were used, considerable heat was imparted to the hearth, and in course of time, to the timber supporting it, which became gradually converted into charcoal (see Chap. I., p. 46).

The introduction of slow combustion grates and tiled hearths entirely altered the arrangement and enormously increased the danger, as it subjected the hearth to more continuous heating, with the result that many fires have been caused by this more modern means of heating, which is entirely opposed to the intention of existing by-laws, unless the hearths are reconstructed with fire-resisting materials.

A very interesting case happened which aptly illustrates this point. In order to show a new pattern of "well" fire, a fireplace had been made upon the most up-to-date lines in a large ironmonger's showroom on the first floor. A small fire was kept burning day and night, but as two of the wooden ribs of the centering used in building the trimmer arch had not been removed, the conducted heat fired them, and they in turn fired the top of the shop fittings against the ceiling on the ground floor. When the premises were opened in the morning the whole of the building was full of dense smoke and considerable (unjustifiable) water damage was done before the seat of the fire was found.

During the demolition of old buildings cases have been brought to light in which timbers have suffered to such an extent that 6-inch square oak beams have been two-thirds charred away, and only the lack of air (oxygen) prevented the complete combustion of the timber.

The origin of a fire in London, on 17th April, 1899, is instructive.

In a recess in a brick-built lift shaft were some wooden bricks, to which was fixed a wooden packing piece, and to this was attached the wooden guides for the lift. The inner faces of the wood bricks were 6 inches (0·15 m.) distant from the iron flue pipe (see Fig. 81) from a steam boiler. One of the wood bricks (see Fig. 80) was entirely consumed, due to the heat from flue, and some others were much burned.

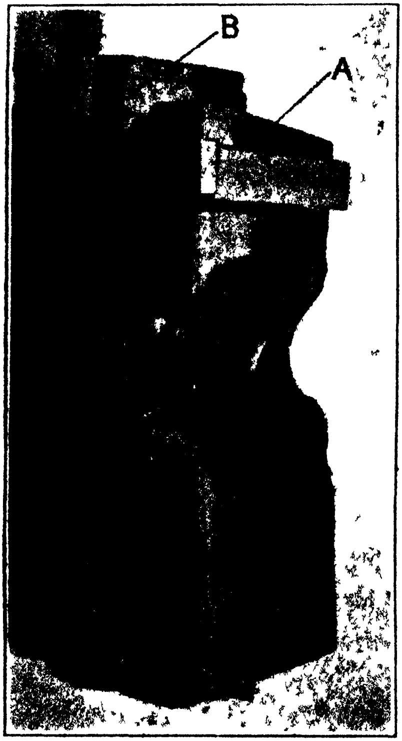


Fig. 80.

Fire was communicated from the burning wood to a bunch of bell and telephone wires coated with paraffin wax and cotton enclosed in a rubber tube about 1 inch in diameter. These coated wires carried the fire to the top of the lift enclosure, where it passed through a glazed door and a trap in the concrete ceiling leading to the extensive and lofty tower 120 feet (37 m.) above the street, which was constructed of pitch pine. The burning of this large quantity of pitch pine at such a height gave the Fire Brigade much trouble; in fact, the pitch pine was entirely consumed, no burned timber or charcoal being left.

Wooden joists have also been found projecting into flues from which the pargetting had fallen away, allowing the ends of the joists to become charred. In time the joists would have been sufficiently burned to allow the fire to pass to more combustible material such as floor boards, etc. (see p. 44).

A good example of a defectively constructed fireplace and flue was furnished in a house in Leeds. A strong smell of fire was noticed in the sitting room, and no cause could be traced for some time. Ultimately it was found that the heat of the fire had passed through the half-brick (0·11 m.) division of the party wall at the back and consumed the woodwork in the adjoining house. The neighbours had no idea of their danger, as the draught up the chimney caused all smoke to be drawn up their sitting-room flue.

Another instance occurred in a large country mansion, a part of which had never been occupied. The mansion stood on the side of a hill. The kitchen flue had been on fire, and burning soot had been driven down another flue some 10 feet (3·05 m.) away. This flue terminated in an empty attic

bedroom and was blocked up at its base with sacking. Passing through this room and crossing the hearth was a large wooden lead-lined trough

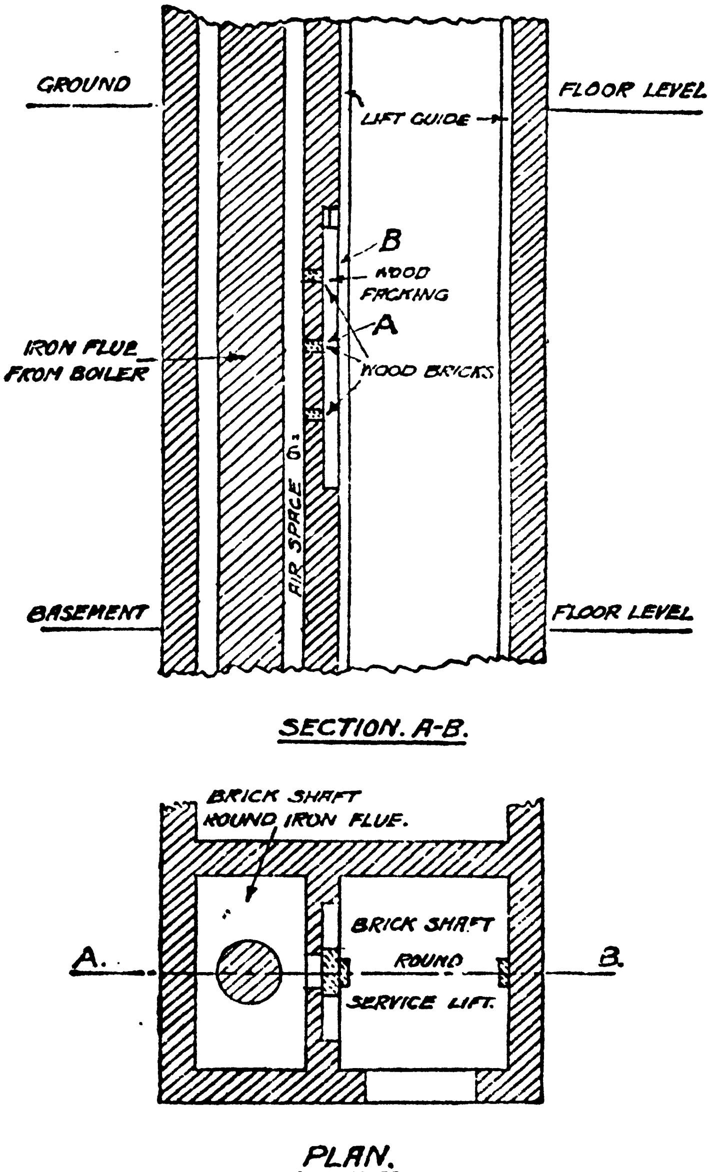


Fig. 81.

for conveying rain-water from the front to the back of the building. The soot fired the sack, which fell into the trough. The fire travelled along

the trough 12 feet (3·66 m.), and, receiving a check at the bend immediately under a lath and plaster partition, attacked the laths and passed up to the roof between the studs of the partition, causing considerable damage. The most remarkable feature was that the bedroom in which the fire started showed hardly any sign that fire had passed that way.

The smell of fire and the presence of smoke should be at once investigated. Many a serious fire would have been prevented if attention had been given to these obvious warnings.

The defective setting of a stove, shown in Fig. 82, allowed such an accumulation of soot at the back of the stove and chimney piece as to cause

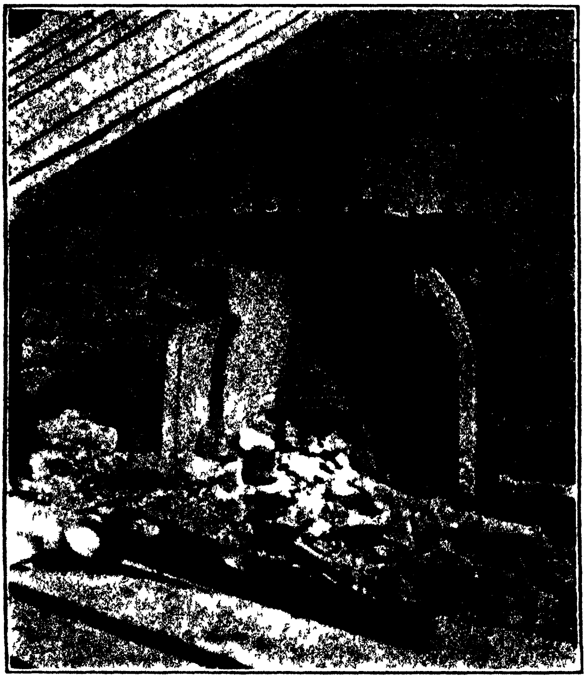


Fig 82.

a fire, by which a woman lost her life, in Islington, on 30th December, 1903. The law should be able to enforce the requirement that all stoves in chimney openings should be set solid so that no space may exist for the dangerous accumulation of soot.

Dangers such as these can only be overcome by strict supervision during the building of a house, or during alterations, and by entrusting alterations and repairs only to workmen who thoroughly understand the work which has to be done.

All chimneys should be regularly swept, also the upper part of slow combustion fireplaces where they join the flues. The backs of register grates should also be cleaned weekly to remove accumulated soot.

When a fire occurs in a flue, it may be extinguished best by throwing salt, brimstone, or sand upon the fire in the grate, and then tightly closing the whole of the fireplace opening. The action of the brimstone is to use up the oxygen in burning, which has the effect of starving the fire in the flue. Better results will be obtained by the use of other substances which will prevent the access of air and thus exclude any fresh supply of oxygen. The " Pyrene " extinguisher is one of the best kinds of portable chemical fire extinguishers for this purpose, and carbonic acid gas in its various forms is also a most effective preventive to oxygen reaching the fire.

(4) **Candles.**—The simple, innocent-looking candle, in common with all unprotected mobile flame, carries within itself a whole host of dangers. It is generally used without any form of protection to its flame (a most uneconomical procedure), and frequently without even a holder. It is stuck about in haphazard manner and in any place, dangerous or otherwise.

A moderate heat will cause any candle to bend over, and when it is used, or rather left, in the careless manner alluded to, it will probably overbalance

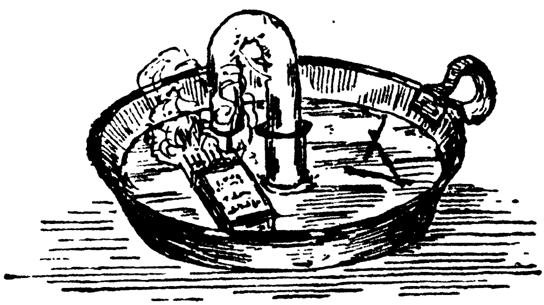


Fig. 83.

to an extent sufficient to cause the bottom to become unstuck, when the candle falls over, frequently with disastrous results.

Matches are often kept in the tray of the candle-stick, and Fig. 83 will explain a case that occurred when the heat of the day caused a candle to droop until the wick came into contact with a box of safety matches, igniting them, also the table-cloth and other small articles, before it was discovered.

It is well known that moths are attracted by flame, and on one occasion a large one flew into a room and floundered through the flame of a candle and ignited one of its wings. It then darted on to a curtain near by, which at once flared up. In this case the adherent wax may have helped the wings to keep alight.

It is surprising how often lighted candles are forgotten and left burning. To cite one instance :—Much damage was caused to the contents and wall-paper of a room through fire which appeared to have originated under a bed. It was afterwards discovered that the servant had been hunting for a missing cat. To assist her search she took a lighted candle, and with its aid discovered the cat under the bed, and thankfully carrying it off, she left the burning candle in its place.

(5) **Oil Lamps.**—With normal mineral lamp oils—*i.e.*, oils with a flash-point of over 73° F. (23° C.) (closed " test point "), the very large numbers of fires caused are mainly due to the faulty construction of some of the cheaper forms of lamp used and to their very general misuse. It should always be borne in mind that, in a warm room, with the aid of the additional heat conducted and irradiated from the burner, it is possible to generate explosive vapour in the body of a partially empty lamp. If an attempt is made to re-fill a still warm lamp by means of a side plug, a fire is nearly certain to occur. No lamps with side feeds should ever be used. Another very common cause of fires is the breaking of glass reservoir lamps by dropping, or the upsetting of a lamp from some flimsy article of furniture. Lamps with glass reservoirs, unless of very strong construction, should never be used ; those with very heavy bases are to be preferred, and stability should, where necessary, take precedence over lines of beauty.

A servant had lit a lamp in the scullery in order to do some work there. She placed the lamp on a chair beside the sink, and put down the matches on the edge of the sink, the waste pipe of which was stopped up, unknown to her. When she returned to the scullery she found that the sink had been filled by a running tap and the overflow had tilted the match box on to the lamp, igniting the matches and causing considerable heat, which might have caused the lamp to explode had she not returned in time to remove the burning match box.

Yet another cause of accident is the attempt to extinguish a lamp by blowing down the chimney. It is often done without thinking. This action reverses the direction of the air currents and tends, with a loose-fitting wick, to ignite any vapour present in the lamp body. The obvious method is to turn the wick well down and then to blow *across the top* of the chimney. This maintains the current in the same direction, and the cooling action of the strong induced flow of air extinguishes the more feeble flame.

A modern lamp should be fitted with one of the automatic extinguishers, of which many reliable varieties are on the market.

Lamps should be refilled daily in order to keep at a minimum the space available for the accumulation of vapour. Allowance should be made for the expansion of the oil. The morning is the most suitable time to re-fill, and the wick should be cleaned at the same time.

Before leaving temporarily the subject of oil, which will be touched upon again later under the heading of " Storage," attention must be drawn to the danger of lighting fires by what is known as the lazy method. The warning is well emphasised in Fig. 83*a* with the words of an American poet:—

Stubborn fire,
  Weather keen,
Cook Maria,
  Paraffin.

Splendid fire,
  Brilliant light,
Cook Maria,
  Angel bright.

"Mrs. J. Colbenson, of Beatrice Street, Liverpool, threw paraffin oil on a fire, to make it burn, once too often. She was 56."—*Fire*, August, 1924.*

(6) **Gas.**—With coal gas, the chief source of danger is to be found in the apparatus provided for its employment, especially when the fittings are old and inefficient; and also when the unprotected flat flame burner is used. The long, three-jointed swing burner, or indeed any kind of bracket, is dangerous when installed within reach of draperies, curtains, etc., which are liable to be moved by the wind or other agency, and every burner

Fig 83A.

should be provided with some sort of guard to prevent contact with the flame. On one occasion eight separate fires were reported in one evening, all of which were found to have been caused by a suddenly rising wind blowing curtains into naked lights. A wire globe is the strongest form of protection, but it should be kept free from accumulations of dust. Glass and combinations of glass and metal fittings are to be obtained which are also quite efficient.

A fire occurred in a tea warehouse and the top floor was burnt out. The cause of the fire could not be ascertained. Upon the lower floors, however,

* See also "The Petroleum Lamp," Thompson and Redwood. C. Griffin & Co., Ltd., London.

it was found that the building was illuminated by incandescent gas burners, some being suspended from the open wooden joists by wire only, and that the supply of gas to some of the burners was through soft rubber tubing from the old fittings (see Figs. 84 and 85).

An error which is frequently met with is that of fitting a gas bracket close beneath the ceiling, and then fixing to the ceiling a piece of sheet iron

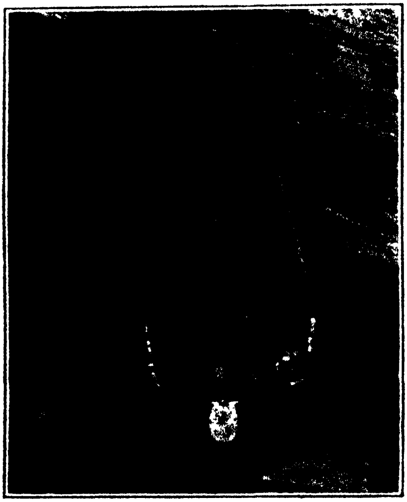


Fig. 84.

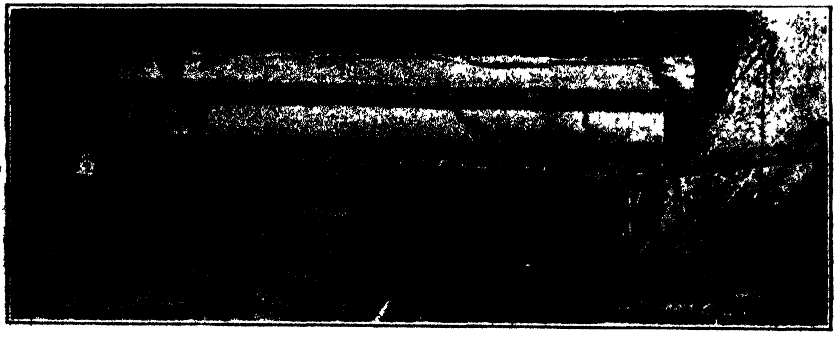


Fig. 85.

as a protector. The least thought should convince anyone that this is quite inadequate, as sheet iron is a conductor of heat, and rapidly transmits it to a limited area of the ceiling, and so on to the wooden laths, timbers, or other combustible materials situated above the plaster. The plaster, too, is probably rendered more conductive by the holes made in it when fixing the iron. There should be a clear 12 inches (0 305 m.) minimum space

between the sheet-iron deflector and the ceiling, to permit the effective dispersal of the heat generated.

Coal gas, when ignited at its point of issue from burner, pipe, or fracture, and under high, or very feeble pressures, burns tranquilly and without danger. If, however, it is allowed to escape and mix with air, the result will be that, between the limits of 8 to 23 per cent. of gas, a readily ignitable explosive mixture is formed. If in addition, there is suspended in the air even a small quantity of carbonaceous dust, serious trouble may be experienced with as little as 3 per cent. of gas. Coal gas is lighter than air (sp. gr., compared with air, ·42), and therefore ascends. Owing to this characteristic it will, if allowed, collect under vaulted ceilings, and above the top of door or window openings, etc., where it will readily mix with the air and remain an ever-present source of danger to the first comer bearing a light. It is incredible, but nevertheless a fact, that some people still insist on searching for an escape of gas with a candle or other form of flame. Coal gas also frequently contains a fairly high percentage of Carbon Monoxide and is therefore poisonous.

The obvious remedy, when an accumulation of gas is suspected, lies in thorough ventilation, with particular attention to high pockets, and thereafter a thorough search for the escape, by orthodox methods. In this connection it should be borne in mind that some electric torches provide a spark sufficient to ignite gas-laden air.

Other gas risks principally arise from the following causes:—

(*a*) Cocks unprovided with proper stops on the plugs.

(*b*) Evaporation or leakage from the hydraulic seal, or the drying of the stuffing-box of sliding chandeliers. There is no excuse for the employment of such obsolete apparatus to-day.

(*c*) The opening of the seam in cheap varieties of brass tube.

(*d*) Gas cocks, particularly those of cookers, being allowed to become too slack, so that the slightest touch against them of a cloth held in the hand, an apron, or a sleeve, will brush them open.

(*e*) In old houses, where lead or "compo" pipe is still in use:—

(i.) Gnawing by rats or mice. This is particularly dangerous when it takes place between floor and ceiling.

(ii.) Piercing of pipes by nails when hanging ornaments. *Apropos* of pipes, the smallest capillary cracks or pinholes may give rise to dangerous leaks, on account of the low density of gas; therefore, all pipes should be tested before being installed. This is a very easy matter, for the pressures entailed are extremely low.

(*f*) Leaks from the street mains and service pipes. These may work their way in through basement walls or up any old, long-forgotten untrapped drains or pipes. These leaks sometimes travel five or six hundred yards when imprisoned under asphalt, flagging, or a frozen road surface. They may be caused by subsidence of the soil, steam rollers, contraction, traffic vibration, breakage of a water main or by electric currents from defective electric cables; electrolysis from stray currents, corrosive chemical action of certain made-up soil, bad workmanship, excavations, etc., etc.

(*g*) That much libelled piece of apparatus, the gas meter, should always be put in some well-ventilated place. With ordinary care it is perfectly

safe, but experience teaches that it is too much to expect ordinary care. The meter really is a wonderfully simple and complete piece of mechanism, which provides for all contingencies, yet, especially with the aid of human carelessness, failure is possible. A bad case may be quoted. A meter of the wet type was installed in a bedroom—quite a common position in flats. The room was occupied by two young girls, the daughters of an engineer. During the day the Gas Company's agent called and adjusted the water level, carelessly omitting to replace the syphon box plug. During the night, whilst pumping was in progress from the works to an outlying gasholder station, the pressure in the town main was suddenly increased and for a few seconds, rose to an unusual height. This " blew " the light water seal off the syphon box, and as the float jammed, gas continued to issue. In the morning both girls were found dead.

A death was caused at Hammersmith in January, 1921. A man 43 years of age was undressing to go to bed, when the gas supplied through a penny-in-the-slot meter went out. He got into bed in the dark and neglected to turn off the gas tap. His brother returned later in the evening to another room ; and finding that there was no gas, placed several pennies in the meter. In the morning the first man was found dead in bed. Had the brother entered this room with a light, it is most probable that an explosion would have occurred.

Escape of gas seems to have been very prevalent during the winter, 1922-3, and a number of accidents occurred ; in each case explosions might have taken place if the vital percentage of gas had been in the mixture. Only a few examples are given.

November, 1922. A young Jersey servant girl was found dead in bed, and investigations showed that a gas pipe in a downstairs room was leaking. The pipe had apparently been gnawed by rats, and gas entering the girl's bedroom had poisoned her whilst she slept.

December, 1922. Three persons affected ; four dead.

January, 1923. A picture fell during the night and damaged a gas bracket ; two persons found unconscious.

Another case occurred in the upper floor of a large factory in which girls worked at sewing machines. Over each machine was an inverted incandescent gas burner fitted with a by-pass. On leaving work each girl turned down her light on to the pilot. The last person to leave opened a window, the wind blew out several of the small pilot jets and the gas escaped into the upper portion of the room, mixing with the air until it became an explosive compound which in time descended sufficiently to ignite from the still burning pilot jets. In this case the windows were blown out, and the building was set on fire.

In another case the occupier of a room on returning from work, found a strong smell of gas ; he promptly opened the window, when the mixture of air and gas in the upper part of the room was forced down to a pilot light on the chandelier, causing an explosion and serious injury to the man.

Also see the case of a church on fire, Chapter XVII.

In lighting gas stoves and heating apparatus generally, care should be taken to apply the lighted match to the burner *furthest* from the tap ; this will ensure that the whole of the air has been expelled from the pipe and burners. If the light is applied while the air and gas mixture is in the pipe an explosion of a more or less violent nature will follow.

The sudden closing of the oven door of a gas cooker will, by the jar, sometimes extinguish the flame from the jets, and, if not discovered, the gas will escape, filling the whole of the oven with a mixture of gas and air. When the door is again opened, the mixture will ascend, and is readily fired by the light from the gas rings above. As the person opening the door is usually stooping at the time, the full force of the explosion is usually received upon the face and upper portion of the body.

Gas-heated laundry or flat irons are now extensively used, but great care is necessary upon the part of the person using them, as if left alight for any time unattended a hole can soon be burnt in a table, and as the iron falls the tubing may be destroyed, the gas from the piping ignited, and all combustible matter in the vicinity burnt.

(7) **Electricity.**—Electricity is often termed "the safest illuminant," etc., but its safety would be greatly increased if it were possible to eliminate the factor of human carelessness.

It is, in its every-day applications, more readily transformed into heat than any other known form of energy, and for this reason, carelessness and want of foresight will do more damage through the agency of electricity than by any other medium.

The Institution of Electrical Engineers have issued an admirable set of general rules which, if rigidly adhered to, will prevent anyone from going wrong. These rules are naturally framed with a view of giving reasonable safety without unnecessarily hampering the industry. In cases of special fire risks, additional precautions may be taken with advantage. In all electrical installations careful initial planning must be followed by equally careful erection and wiring. The engineer must employ a high percentage of skilled labour, and must use only the best apparatus and materials, controlled by active and competent men; and periodical examination and testing of all circuits and apparatus must be arranged for.

Beware of alterations and additions. These must always require consideration with the installation as a whole, and must be duly plotted on the drawings. Nothing is more fatal than haphazard tinkering with an originally good installation. If these simple precautions are borne in mind no trouble from a fire point of view need be expected.

Temporary installations, which often drag on for a long time, are a constant source of trouble. They are peculiarly liable to accidental damage to the insulation, and will need extra careful supervision. Beyond keeping the circuits to as small an amperage as possible, with correspondingly low fuses, there is little that can be done in the way of protection.

In installations of large size, tell-tale instruments, such as recording ammeters on each main circuit, should be installed, to give the responsible engineer valuable information, and to warn him of coming trouble. It must be borne in mind that one brief overload may cause the commencement of the breakdown of the installation, which may subsequently give way altogether, without any apparent reason.

On minor circuits it is well to have (at a little extra expense) cartridge fuses only, and to issue these only in a small number at a time to the operatives.

Whenever there is an abnormal demand for certain fuses, it should be investigated in company with the operative responsible, in order that any

difficulty may be removed. It is astonishing what people will do with fuses if left to their own devices. In one case, a blacksmith of excessive initiative, but small intelligence, had trouble with the fuses of a certain motor circuit which were blowing pretty frequently, and caused him annoyance. He decided to put a stop to the annoyance once and for all, and carefully forged for himself a set of three stout iron fuses many times the section of the line. Fortunately, before serious damage was done, his activities were nullified by the main automatic switch jumping out. "Excess amperage," "no voltage," and "leakage cut-out" automatic switches should be provided on main circuits in addition to fuses and lightning protectors. About workshops, where dust is more or less unavoidable, motors of the enclosed type should always be used. All starting devices also should be enclosed, and fitted with a "no-volt" release. These appliances add to the cost, but the smooth working, extra reliability and security well justify the additional expenditure. All dangerous precincts should be efficiently fenced off in order to protect the staff, as well as the inquisitive, the careless, children and domestic animals, and incidentally the plant. Perforated metal, mounted on "T" frames, is well adapted for this purpose. Much commotion was caused at a works by a cat crawling in through a ventilation aperture of a transformer sub-station of 8,000 to 180 volts, three-phase A.C., and leaning up against a primary bar. The cat was carbonised, and a whole district plunged into darkness.

The constant necessity of carefully reviewing the positions of, and eliminating all possible accidental contacts between the primary and secondary transformers, should be borne in mind. Such a contact may, on high and even comparatively low tension A.C. installations, have far-reaching and disastrous consequences.

On the southern slopes of the Alps, where water comes down from the melting glaciers with great force, installations abound where A.C. current is generated at fairly high tension, again stepped up by transformers, and distributed by overhead lines to distant villages where at transformer substations it is reduced to normal voltage and utilised, at very cheap rates, for power and lighting purposes. A few years ago at one of these transformer sub-stations near Lecco on the Lake of Como, through some unknown cause, a contact between primary and secondary took place.

Instantly throughout the village habitations served, the wiring began to glow and throw off sparks of burning insulation. Instinctively the unfortunate inhabitants rushed to the switches to cut off the current, and as they touched the fatal handles died like flies, with those who tried to save them. In a few seconds all was over, for a thorough "burn-out" cut off the current; but in the meantime many lives were lost, and several fires started.

The best of insulation will break down eventually if exposed for a sufficient length of time to heat, warm moisture, grease, vibration of machinery, friction caused by swaying, etc.

In any building where there is the possibility of the accumulation of explosive vapour, gases or dust clouds, all fuses, switches, etc., indeed any apparatus capable of producing arcs or sparks, should either be enclosed in *really* gas-proof uninflammable enclosures, or, preferably, be situated outside the risk in weather-proof boxes.

It must not be forgotten that when accumulators are used a certain

amount of water is decomposed or resolved into the gases of Hydrogen and Oxygen, and these may form a highly inflammable and explosive mixture, and that, therefore, effectual ventilation is necessary.

Extreme cleanliness, order, and method are essential to the successful working of any electrical installation. Connectors with their roughly handled cables for portable apparatus are a constant source of danger, particularly when working in a possibly explosive atmosphere. It must not be forgotten that the popular electric irons and radiators are a source of danger if left in too close contact with inflammable draperies, etc., or allowed to stand on an unprotected wooden table. It would be well if every appliance of this kind were fitted with switch attached to the handle so that the current is on to the iron only when the handle is grasped, and in every case a red light should show when the current is on. A case occurred at a large country house where an electric iron was left standing on a table with the current on, and during the night it burnt through the table and the floor under it, causing nearly complete destruction of the mansion.

Connections to overhead lights require watching. Some years ago in a theatre in London (as well as one at Milan), the main chandeliers, which were suspended by a steel cable, had by the side the wiring of the numerous clusters. The gentle swaying of the huge fittings, coupled perhaps with not inconsiderable heat, gradually broke down the insulation, until one day with a flash and a bang down came the whole into the auditorium.

Electric lamps themselves, although very innocent looking, require careful attention. An arc with a broken globe and the bottom guard missing is a first-class distributor of incendiary sparks of incandescent carbon. The incandescent lamp itself is a fairly strong source of heat, and if enclosed in close contact with inflammable decorations, draperies, etc., it may cause a fire. It is the old story again. If more heat is supplied to an object than can be conducted and radiated away, the temperature gradually rises to "*ignition point*," and the result is fire.

The old carbon filament retains heat for an appreciable time after the breakage of the bulb, and experiment has demonstrated that even after falling several feet it is still hot enough to ignite cotton wool, a most dangerous form of decoration, second only, perhaps, to fluffy flannelette. To this cause, or the direct contact of the bulb with inflammable material, was attributed the disastrous fire at Battersea in 1909, when eight persons lost their lives and the building was totally destroyed. Another danger of the incandescent lamp of the hanging or portable variety, is the facility with which it can be put away and forgotten until too late. Quite recently a serious fire was caused by an employee in a large warehouse putting a lamp with a wandering lead out of his way on a shelf during the daytime, and forgetting it was there. The lamp with several others was controlled by a single switch, and, in its forgotten position, was resting against celluloid goods. When lighting up time came round, after a little preparatory warming, the celluloid "went up."

Wireless.—A new or rather an increased danger from fire has been forced upon the authorities by the enormous number of wireless installations that have been fixed since the year 1918.

These installations, being easily and cheaply erected, are to be found

in almost every street, and in some streets nearly every house has its aerial.

The danger of fire from this new pastime is enhanced by the fact that little knowledge and expense is required to fix an installation in any position.

The danger from lightning may, or may not, have been provided against by special fuses, but the care necessarily required to disconnect or ground the wires when the atmosphere is abnormally charged with electricity or during thunderstorms is often neglected.

The great danger accompanying the installation of wireless apparatus is the careless treatment to which it is often subjected. The haphazard way in which the charging of accumulator cells is carried out has already caused a large number of fires. Various reasons may be mentioned. Loose ends of wire left lying about causing short-circuiting; filling cells with an excess of acid so that, when the charging is proceeding, the ebullition of the gas causes an overflow which so heats up any combustible materials near that they take fire and in turn set the celluloid casings alight.

Repairing celluloid cases without due regard to the highly inflammable nature of the celluloid and the cementing solvent (usually amyl acetate).

It is also a common practice to leave the cells on charge all night and not infrequently to find them consumed in the morning, even if nothing worse has resulted.

Bitumen Gas Explosions.—A number of explosions have been caused by the use of bitumen in laying electric cables, and in a report of a committee to the President of the Board of Trade in 1914, it was stated that during the preceding eleven years, seven serious explosions had taken place in houses, due to the ignition of vapour generated by short-circuits between electric cables laid underground in the streets. These caused the death of two persons and injury to seven others. Explosions have, and still, occur from similar causes in manholes of street boxes, and several persons have been injured by these, while there have been many cases of minor explosions which have merely raised the lids of manholes or have disturbed the pavement. There have been also explosions in electric street boxes due to the accumulation of coal gas from leaks in defective gas mains.

No serious cases have been recorded, where the supply was given by alternating current, by concentric mains, or by lead-covered, paper-insulated cables; and three-core cables may be added to this exclusory list.

Bitumen and similar compounds serve excellently as insulating material, so long as the cable is not overloaded. Should the wires become hot, either locally at a breakdown or short-circuit, or along a length which is carrying current to a short-circuit, the bitumen is melted, boiled, and converted into vapour at such a pressure that it will be forced violently through any passage, even through iron boxes filled with gravel. Even a very small quantity is highly explosive.

To prevent explosions from the above causes, or from coal gas, it is recommended that a systematic and frequent inspection of street boxes should be made by the electric supply undertakers, and that they should report at once to the gas companies any leakages found or suspected.

Neon Gas is now being used as a method of advertising.

The tubes forming the letters of the signs are made of glass fitted with copper Electrodes at each end. A vacuum is created in the tube and Neon

gas introduced. This gas when excited by electricity gives an exceptionally brilliant red glow.

According to the size of the tubes the voltage of the electric current varies. Large letters such as are sometimes employed are 21 feet long—in these cases a high voltage running to 7,500 is required. As these large letters are made up of several tubes, there are the various connecting wires which are not insulated, and these are necessarily a serious source of danger to life. The amperage used is small, so that the risk of fire is comparatively slight. Neon gas being inert, there is no risk of explosion. The current is usually taken from the ordinary source of supply and special transformers installed as near the sign as possible. Insulated cable is used between the letters and the transformer. Every transformer should have an effective switch out of reach of the general public, but readily accessible to authorised persons (firemen, etc.), so that before any part of the sign proper is approached for any purpose the current can be cut off. Such a switch would obviate the necessity of other elaborate precautions which would otherwise be absolutely essential.

(8) **Petrol—Petroleum Spirit.***—Everyone should know that petrol is a dangerous substance, but people are so familiar with it that perhaps they do not take its dangers as seriously as they should. In reality they are very great indeed. Petrol is volatile even below freezing point, it floats on water, and gives off vapours which, mixed with air, form highly explosive compounds. These inflammable vapours are nearly three times as heavy as air, and consequently have great migratory powers. The danger-laden layer of vapour creeps on along the floor, drawn by the draught, until it reaches an open fire, a gas jet on the stair, or even in a room below, or an unextinguished match thrown down in the yard apparently well out of range. There it ignites and the flame darts back to the source of the vapour, just as along a trail of powder; and before an alarm can be given the place is on fire. Under these conditions flame will leap back over 30 feet (9·14 m.). A case occurred where a woman had been cleaning a garment with petrol and poured the waste spirit down the sink. Shortly after an explosion occurred in the yard 25 feet (7·62 m.) below, and an iron manhole cover was hurled with great force against a wall. The trap in the sink was also blown out with great force. The very dangerous property referred to above is common to the vapours of many other liquid hydrocarbons and mixtures, such as benzol, ether, carbon disulphide, etc. The vapour of alcohol has this property to a lesser degree.

All buildings in which inflammable hydrocarbon vapours are likely to be formed should be isolated from any possible source of ignition, including fires, gas jets, electric sparks, arcs, fuses, etc. Thorough ventilation must also be provided to all floors, including sunk floors or engine pits. It is a grave offence to allow petrol to get into the drains, where it may cause very serious explosions.

Petrol and its companions will very readily find their way through an imperfect joint of any kind, and whenever possible metal connections should be used. When some form of jointing is unavoidable its base should be of soap, which is insoluble in these liquids. Any jointing substance held

* This subject is admirably dealt with in "The Storage of Petroleum Spirit," by Major A. Cooper-Key. (C. Griffin & Co., Ltd., London.)

together by oil is rapidly rendered useless by the dissolving out of the binder.

Petrol vapour lurks dangerously in so-called empty petrol tins and receptacles. All such tins and receptacles should be treated with the greatest suspicion and respect, and all the caps replaced and screwed down tightly as soon as the tins are emptied, for with the cap on any vapour in the tin is confined and safe, but without the cap the vapour can escape, and if mixed with air in the right proportions it may be fired or exploded by a flame some distance away. A case occurred in which four little children were playing in the sun with a so-called empty tin and matches. Two of them lost their lives and a third was badly injured. Another example is provided by the following incident:—A motor petrol tank was carefully drained and well rinsed twice with water. It was then filled three times with water and allowed to flow over for three minutes. When the tank was again emptied and some minutes later a gas flame was brought near, a violent explosion occurred. This tenacity of petrol is due to the insolubility of petrol in water, and to the fact that greasy globules of the heavier distillates form on the sides of the tin. It is impossible to be too careful in dealing with petrol "empties."

The inlets of all receptacles should be provided with double wire gauze cones, which, working on the well-known Davy lamp principle, will cool down the flame and prevent its propagation to the interior.

The cones must be flanged and strongly secured by a screw-down ring, and not by soldering. These gauzes also act as filters and eliminate many "engine" troubles. Receptacles thus fitted are inexplodable *as long as the portion above the level of the liquid is not heated at some point to redness.* Absolute security can only be obtained by filling that portion with an inert gas. This will be dealt with more fully under "storage."

The L.C.C. regulations are given on pp. 176 to 180.

Petroleum, or oils giving off an inflammable vapour at less than 73° F. (22·7° C.), when conveyed by ships or barges on the River Thames, come under strict regulations. Notices are required to be given to the Port Authorities, whose instructions must be complied with. These govern the storage and discharge of the oil, the ventilation of the vessels, the distance, 100 feet (30·5 m.), between ships when moored and not at the time being laden or discharged, also the display of a three-feet (0·91 m.) red flag with white disc, 6 inches (0·15 m.), or a red light on the masthead. Before any petroleum in barrels, drums, or other vessels is discharged from a ship the holds have to be thoroughly ventilated, and when empty well cleaned. This cleaning does not apply to tank steamers, which are leaving the Thames immediately.

Amongst other regulations are the following:—

No fire, smoking, matches, or artificial light (except an approved safety lamp) are allowed on board.

Leaky barrels may only be discharged at duly licensed wharfs, and not into any other vessel.

No movement of petroleum is permitted between sunset and sunrise. The tanks must not be filled above 2 inches (0·05 m.) below the base of the expansion chambers.

All manholes, valves, and suction pipes must be closed gas-tight, and ventilators covered with wire gauze before a vessel is moved.

Petroleum or water from the bilges must not be discharged into any confined waters.

Barges without self-propelling power must not exceed 250 tons.

Self-propelled barges must not exceed 500 tons, must be of iron, and have for their motive power internal combustion engines fitted in the stern, in which the ignition is effected otherwise than by any form of spark, flame, or hot tube. The exhaust gases must be discharged below the water line. The oil for power must have a flash point of not less than 150° F. (65·5° C.).

Every self-propelled barge must carry cylinders charged with carbon dioxide gas under pressure and of such a volume that when discharged the gas will occupy one-fifth of the engine-room.

The cylinders must be fixed in a cool place outside the engine-room, and must be fitted with fusible plugs capable of being punctured from the deck. One cubic foot (0·03 $m.^3$) of dry sand is to be carried for each 20 feet (6·1 m.) length of hull.

(9) **Celluloid.**—This material is to be found everywhere under every conceivable form and disguise. It is used, for instance, as the base for cinematographic and photographic films.

Celluloid is essentially a gelatinised, mechanical mixture of nitro-cellulose (somewhat similar to gun cotton), camphor, and, generally, some colouring matter. To this mixture special compounds are sometimes added to increase and maintain its flexibility. Two varieties are in general use—namely, one that is used in the manufacture of cinematograph and other photographic films, which is less dangerous than gun cotton in that it is less highly nitrated, and the other which is used for making toilet and general articles. This latter variety of celluloid is of a still lower nitrate and consequently slightly less dangerous than the former. Both are highly inflammable. Good celluloid ignites between 302° F. (150° C.) and 350° F. (177° C.) *without* contact with flame, and, as it contains in the admixed nitro-cellulose sufficient oxygen to support combustion, it will burn in hermetically sealed receptacles and even under water. This latter remark more particularly applies to cinematograph film.

The action of heat causes celluloid to "fume"—*i.e.*, decompose with the evolution of considerable quantities of gas, which are readily ignitable.

Fuming points of celluloid made in 1911 upon fully seasoned samples, the storing of which under normal conditions would not affect the fuming point, gave the following results:—

Class.	No. of Samples.	Fuming Points.		
		Minimum.	Maximum.	Average.
Clear Base Amber and Blonde,	112	306° F. 152° C.	338° F. 170° C.	326° F. 163° C.
Shell and Demi-Blonde,	82	316° F. 158° C.	342° F. 172° C.	332° F. 167° C.
Containing Pigments,	162	334° F. 168° C.	390° F. 199° C.	350° F. 177° C.

Celluloid in itself cannot be considered explosive under practical everyday conditions, but, working under laboratory conditions, pressures up to nearly 45,000 lbs. per square inch (3,000 atmospheres) have been noted on firing it in a bomb. Only one authentic case of detonation has been brought to the notice of the writer. This was caused by accidental friction in a machine, and caused serious damage. Under experimental conditions it has not been possible to re-obtain detonation; this danger can, therefore, be considered only as a latent possibility. On the other hand, celluloid burns with great rapidity with a flame temperature of from 2,750° F. (1,500° C.) to 3,100° F. (1,700° C.). This very rapid combustion is frequently incomplete, and then the risk of explosion of the evolved gases arises. These gases produced by incomplete combustion are:—

Carbon Dioxide.
Carbon Monoxide.
Methane.
Hydrogen.
Nitric Oxide.
Nitrogen.
Hydrocyanic Acid (Prussic Acid).

It is probable that celluloid dust, found in manufacturing operations, may be the cause of a violent explosion, and it is conceivable that an electric spark, caused by friction, would readily cause ignition.

It will be noted that, besides the risk of explosion, the deadly poisonous gases, carbon monoxide, hydrocyanic acid (prussic acid), and nitric oxide, have to be dealt with, thus adding considerably to the difficulties and dangers of a celluloid fire, once started.

As with everything else in this world, there are good and bad celluloids. Some of the latter will flame at 302° F. (150° C.), and in isolated cases have been known to ignite with very gentle heat coupled with slight friction. The poorer qualities of celluloid are also subject to the danger of spontaneous combustion arising from the decomposition of the admixed nitro-cellulose. This may be due to initial instability of the nitro-cellulose used, or to excessive heat employed during the processes of manufacture. Celluloid then, although often a very useful and efficient means to an end, must only be employed with due care and precaution. Without doubt, during recent years the stability of the nitro-cellulose, and consequently the relative reliability of the mixture, has vastly improved, but it has not been possible to eliminate its very ready inflammability. Although a fruitful source of static electricity when subject to friction in a dry atmosphere, it is not effected by electric sparks or electricity generally, but it is extremely sensitive to flame and radiant heat; also its action is uncertain when exposed for a considerable time to temperatures even lower than that of boiling water.

Amongst the many cases recorded of the combustion of celluloid adornments, is that of the ignition of a comb in a lady's hair, brought about merely by standing *near* a lighted gas-jet, *without any contact with the flame*, the radiant heat being alone sufficient. To cite another example:—Quite recently a fire in a chemist's shop was caused by a concave shaving mirror focussing the feeble rays of a sickly London sun on the celluloid lid of an ointment-pot. Mirrors such as this have also ignited other materials.

Table copied from British Fire Prevention Committee's Red Book No. 179.

Some Cases in Private Life of Celluloid Fires on the Person or in Dwellings.

Date.	Lives. Lost	Lives. Inj.	Town.	Trade.	Cause and Particulars.
—/6/97	—	—	Wolverhampton.	Private Dwg. House.	Lighted taper falling on celluloid keys of organ.
29/1/98	—	1	Newcastle.	... ...	Burning creosote on collar.
2/1/99	—	-	Birmingham.	... ...	Sparks falling on celluloid thimble.
—/11/02	—	—	—	Amateur Photographer	Celluloid dishes placed on kitchen boiler top.
10/8/04	- -	- -	—	Private Dwg. House.	Candle shade falling on celluloid.
—/—/05	—	—	Kilburn.	,,	Drying dog in front of fire; comb ignited.
13/9/06	1	2	Moffat.	,,	Reading near fire; comb ignited.
—/2/08	1	—	Workington.	,,	Spark from fire on comb.
4/10/08	—	—	Rottingdean.	,,	Sun's rays on combs on dressing-table.
—/9/09	1	—	Sheffield.	,,	Heat from fire whilst cleaning grate ignited comb.
30/3/10	1	—	Gainsborough.	,,	Making toast: comb ignited.
5/6/10	—	—	London.	,,	Toy cinematograph machine.
14/9/10	1	—	Shrewsbury.	,,	Match thrown on collar.
13/10/11	1	—	Liverpool.	,,	Standing near lamp. Hair caught fire and ignited comb.
—/4/12	1	—	Sheffield.	,,	Candle ignited collar.
26/9/12	—	—	London.	,,	Toy cinematograph lantern
12/10/12	—	1	,,	,,	Experimenting with films.
—/1/13	—	1	Richmond, Yorks.	,,	Cleaning hearth; spark from fire on comb.
6/1/13	—	—	Chichester.	,,	Matches on collar.
6/1/13	—	—	Sunderland.	,,	Spark from arc lamp on collar.
25/3/02	—	—	Berlin.	Dwelling.	Carelessness with light.
11/2/06	—	—	,,	,,	Celluloid combs in box: box behind hot oven.
26/4/06	—	—	,,	,,	Film. Unknown.
21/7/09	—	—	,,	,,	Celluloid in kitchen. Carelessness.
20/11/12	—	1	Hamburg.	... ...	Celluloid comb in child's hair, too near kitchen lamp. Comb caught and then clothes.
20/2/00	—	—	Leipsic.	Bedroom.	Burning cigar laid on celluloid dish.

TABLE—*Continued.*

Date.	Lives. Lost	Lives. Inj.	Town.	Trade.	Cause and Particulars.
14/1/01	—	—	Leipsic.	Bedroom.	End of glowing match falling on celluloid soap dish.
7/2/02	—	—	,,	,,	Heat of spirit lamp near celluloid comb.
10/5/02	—	—	,,	,,	Match on celluloid comb.
11/11/02	—	—	,,	Sitting-room.	Glowing match on celluloid comb.
24/11/03	—	—	,,	Bedroom.	,, ,, ,,
31/1/04	—	—	,,	Sitting-room.	Flame of spirit lamp on celluloid comb.
28/6/05	—	—	,,	,,	Glowing end of match on celluloid comb.
16/9/05	—	—	,,	Bedroom.	Candle on celluloid hair-pins.
20/2/06	—	—	,,	,,	Glowing end of match on celluloid comb.
15/5/06	—	—	,,	Kitchen.	Celluloid shavings touched with hot fire-irons.
15/5/06	—	—	,,	Sitting-room.	Candle on celluloid comb.
4/10/06	—	—	,,	Bedroom	,, ,, ,,
29/1/07	—	—	,,	,,	,, ,, ,,
11/4/07	—		,,	,,	Flame of spirit lamp blown against celluloid combs.
6/5/07	—	—	,,	Sitting-room.	,, ,, ,,
20/6/07	—	—	,,	Bedroom.	Glowing end of match on celluloid comb.
28/8/07	—	—	,,	,,	,, ,, ,,
8/9/07	—	—	,,	,,	Flame of lamp blown on to celluloid comb.
17/10/07	—	—	,,	,,	Candle on celluloid comb.
5/11/07	—	—	,,	,,	Match on celluloid tray.
27/12/07	—	—	,,	Sitting-room.	Match on celluloid comb.
13/1/08	—	—	,,	Kitchen.	End of match on celluloid comb.
18/2/08	—	—	,,	Sitting-room.	Cigar on celluloid comb.
18/3/08	—	—	,,	Kitchen.	Celluloid brushes and combs put to dry on stove.
6/5/08	—	—	,,	Bedroom.	Flame of spirit lamp blown on celluloid comb.
1/6/08	—	—	,,	Spare room.	Heat of spirit lamp on celluloid combs.
26/9/08	—	—	,,	Bedroom.	Match on celluloid comb.
14/11/08	—	—	,,	,,	Match set fire to tablecloth and celluloid comb thereon.
28/11/08	—	—	,,	Sitting-room.	Celluloid comb on petroleum lamp.
4/12/08	—	—	,,	Bedroom.	Match on celluloid comb.
8/12/08	—	—	,,	,,	,, ,, ,,

TABLE—*Continued.*

Date.	Lives. Lost	Inj.	Town.	Trade.	Cause and Particulars.
20/12/08	—	—	Leipsic.	Sitting-room.	Heat of gas lamp fires celluloid comb.
2/2/09	—	—	,,	Kitchen.	Celluloid brushes put on oven to dry.
16/2/09	—	—	,,	Sitting-room.	Match touches film of child's cinematograph apparatus.
25/2/09	—	—	,,	,,	Overheating of spirit lamp near celluloid combs.
7/3/09	—	—	,,	Bedroom.	Flame of spirit lamp blown against celluloid combs.
4/9/09	—	—	,,	,,	Flame of candle blown against celluloid combs.
25/10/09	—	—	,,	,,	End of match on celluloid combs.
11/12/09	—	—	,,	Kitchen.	Match on celluloid comb.
22/12/09	—	—	,,	Bedroom.	,, ,, ,,
22/12/09	—	—	,,	Kitchen.	Celluloid comb on cooking stove.
25/12/09	—	—	,,	Drawing-room.	Candle on celluloid comb.
18/1/10	—	—	,,	Bedroom.	Flame of candle blown on celluloid hairpins.
20/3/10	—	—	,,	,,	Portion of burning candle on celluloid hair ornaments.
2/4/10	—	-	,,	... ...	Flame of spirit lamp on celluloid hair ornaments.
30/4/10	—	—	,,	Bedroom.	Burnt-out candle on celluloid hairpins.
1/5/10	—	-	,,	Kitchen.	Flame from stove on celluloid comb.
9/3/11	—	—	,,	Sitting-room.	Heat of flame fires child's cinematograph apparatus.
25/12/11	—	—	,,	,,	Light brought too near child's cinematograph apparatus.
26/12/11	—	—	,,	Bedroom.	Heat of petroleum flame too near film of model apparatus.
11/6/12	—	—	,,	,,	End of match on photograph film.
15/12/12	—	—	,,	,,	Celluloid letter plate fired by candle.
7/6/11	—	—	Blanchard, U.S.A.	... ...	Farmer working in field on hot day (100° in the shade). Suns' rays focussed by steel shovels on to his artificial leg, composed of lines and sections of celluloid, which was shattered by an explosion.

Celluloid, then, in all its many forms, be it collars, cuffs, combs, buttons, handles of cutlery, ornaments, photographic accessories, toys, etc., must be kept at a distance of at least 20 inches (0·51 m.) from any source of heat irradiated from oil, gas, electric light, open fires, radiators of all kinds, etc.

(10) **Spontaneous Combustion.**—There is much to be said on this vast subject, the very wide limits of which are so difficult to define.

The crux of spontaneous combustion is the oxidation of finely divided matter, generally of a carbonaceous nature. This oxidation generates heat, which, owing to the non-conducting character of the matter acted upon, is not dissipated as fast as it is formed. Consequently the temperature rises, and, in conformity with the general law of chemistry that heat favours and increases the rate of chemical combustion, oxidation proceeds at an ever-increasing pace until the temperature of ignition is arrived at and fire breaks out.

Two main classes have to be contended with. The certain or "active," and the possible or "latent." To the first class belong all definite chemical reactions resulting in the production of light and heat, or the process known to us as combustion, and including those special reactions which do not require the presence or agency of oxygen, such as the combustion of iron filings and sulphur, or the union of chlorine with hydrogen, and various hydrocarbons.

To the second class belong the dangers lurking within a very large number of carbonaceous goods when certain of the following physico-chemical conditions, varying in number according to the particular substance, are fulfilled :—

(1) Storage in bulk.

(2) Minute state of subdivision, or fine porosity, providing a large surface for the absorption of oxygen.

(3) The presence of substances avid of oxygen, particularly boiled linseed oil.

(4) Poor facilities for ventilation or the subtraction of heat.

(5) The presence of moisture.

(6) External sources of heat to start the reaction.

(7) In the case of freshly won coal, the replacement by oxygen of the methane (fire damp) occluded in the pores.

(8) The presence of pyrites (iron sulphide), indeed metallic sulphides generally, including calcium sulphide, more especially when moisture and the presence of finely divided carbon coexists.

(9) The presence of oxygen "carriers" of such widely different characteristics as chlorate of potash, saltpetre (potassium nitrate), bleaching powder (calcium hypochlorite), and oil of turpentine.

An important sub-class is constituted by certain metals when in a finely divided state. Of these the fireman is likely to meet aluminium, magnesium, iron, zinc, and bronze powders. These metals are either directly combustible and capable of causing dust explosions, or possess the dangerous property of decomposing water or moisture. Under such circumstances, water is changed from its normal condition of a definite chemical compound to a

mere mechanical mixture of oxygen and hydrogen, thus forming the highly explosive oxy-hydrogen gas.

The bulk of the reactions are of a purely chemical nature; but in some cases, bronze powders for instance, true electrolysis of water is probable. The industrial compound, "Thermit," which is merely a mixture of powdered aluminium and ferric oxide (an oxygen carrier), makes use of this property of aluminium of generating intense heat. Powders of the metals named above should never be allowed to come into contact with water or much moisture, particularly when the moisture is accompanied by heat, and should be kept away from oxygen carriers, acids, or strong caustics.

Firemen should be generally conversant with the fire risks of the "Active" class or oxygen carriers and tackle them with care, and thus avert serious trouble. On the other hand, the fire risk of the numerous "Latent" classes is too often thought little of, or even disregarded altogether, and consequently the position of such as treat the matter lightly is that of a man sitting down to smoke on an open powder keg.

A case in point:—The dirty oily waste that the mechanic throws carelessly under the bench, perhaps against a hot water pipe, is a very common cause of fire, and one that can be understood after making the following experiment:—

Take a rough wooden box measuring internally, say, 8 inches (0·2 m.) on all sides, fitted with a "nail-down" lid, and provided with a quarter-inch (0·006 m.) hole in the centre, to permit the periodical insertion of a maximum thermometer registering up to not less than 300° F. (149° C.).

Take also some cotton waste, previously well dried; soak it in boiled linseed oil, and wring it out moderately dry. Fill the box with it to within an inch of the top, and press it down lightly. Within 24 hours it will break into flame. In cold damp weather it is necessary to warm the box and its contents up to 70° F. (21° C.), quite a common spring and summer temperature. As the bulk of the carbonaceous mass is small it must not be exposed to cold, otherwise the heat generated will be dissipated as fast as formed, and "ignition point" will not be reached. An experiment was carried out in 1918, the following thermometer readings were obtained (see "A" on graphs, Figs. 86 and 87):—

9 a.m., ...	70° F. = 21·1° C.
10 a.m., ...	79° F. = 26·1° C.
11 a.m., ...	90° F. = 32·2° C.
12 a.m., ...	96° F. = 35·5° C.
12.45 p.m., . . .	104° F. = 40° C.
2 p.m., ...	120° F. = 48·8° C.
2.30 p.m., . . .	133° F. = 56·1° C.
3 p.m., ...	160° F. = 71·1° C.
3.30 p.m., . . .	230° F. = 110° C.
4 p.m., ...	260° F. = 126·8° C.
4.45 p.m., . . .	300° F. = 148·8° C.

Another experiment made in 1919 with clean cotton waste soaked in boiled linseed oil and placed in a cardboard box 4 inches (0·1 m.) × 4 inches

(0·1 m.) × 6 inches (0·15 m.) high gave the following rise in temperature (see " B " on graphs, Figs. 86 and 87) :—

	12 noon,	70° F. =	21·1° C.
	4.30 p.m.,	80° F. =	26·6° C.
	5.0 p.m.,	95° F. =	35·0° C.
	5.30 p.m.,	150° F. =	65·5° C.
	6.0 p.m.,	420° F. =	215·5° C.
At	6.15 p.m.,	440° F. =	226·6° C., the cotton was

charred right through ; unfortunately, the premises had to be closed before the ignition point was reached.

The graphs of the two experiments show the influence of temperature on the speed of oxidisation. This will bring home to the reader how very

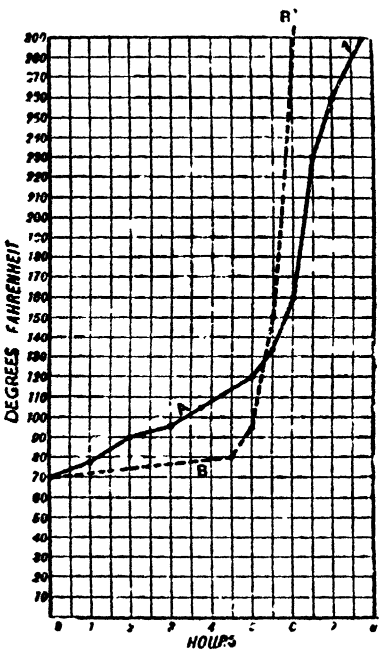


Fig. 86.

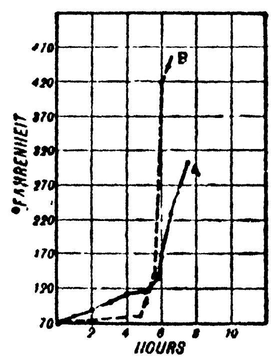


Fig. 87.

necessary it is, when dealing with finely divided oxidisable matter in bulk, to eliminate possible external sources of heat.

The box in the first experiment was left to itself on a sheet of glass in the middle of a yard. In the morning all that remained to collect from the cracked glass sheet was a couple of handfuls of warm ashes, for the bulk of the box and its contents had been consumed.

The chemical action underlying this experiment is the same story of the exposure of minutely divided carbon to the action of oxygen. In fact, the minute tubes of the carbonaceous cotton fibre present an immense surface on which the boiled linseed oil eagerly combines with oxygen. The same result can be obtained, but much more slowly, when dirty waste, greasy

with practically new oil, is left lying about, in a dirty, untidy, ill-managed engine-room or workshop.

Paints and varnishes containing a high percentage of boiled linseed oil will, of course, cause the same results. From the point of view of spontaneous combustion, oils, and greases stand in the following order :—First, vegetable ; second, animal ; and third, mineral.

In the case of the spontaneous combustion of manures, fodders, and cereals, it has been determined that the initial heating is caused by bacteria, which are capable of raising the temperature to 158° F. (70° C.), at which heat they perish. Their action is generally limited to about 130° F. (54° C.), beyond which temperature chemical action sets in. In the case of freshly cut fodders there is another factor to take into account. The vegetable cell retains its vitality for some time after the reaping, and respiration continues, generating heat, and thus creating a favourable temperature for the multiplication of bacteria. The knowledge that we have to contend with bacteria explains how it is that contact with a small quantity of damp, decaying material is liable to extend the damage to a whole heap of otherwise excellent produce.

An extreme case of the action of fire by spontaneous combustion may be quoted in the example of a tree uprooted by a storm and left to rot, or in other words to oxidise slowly, which is the same process as burning. In the course of many years the tree will disappear, slowly converted, although without appreciable rise of temperature, into (principally) carbon dioxide and water vapour. This is nature's favourite method of scavenging. This must not be confounded with the dreaded forest fire caused by a carelessly extinguished camp fire, a spark from an engine, or by friction, which is the most ancient method of obtaining fire. It is easy to picture the scene. An opening in the forest strewn with fallen trunks in all stages of decay ; all the country round is parched, stricken by prolonged scorching drought. A heavy hanging branch, swayed by the wind, rubs clumsily against the rotting trunk of one of the fallen trees. Suddenly a faint spark arises, only to die away ; then another and another, till finally one finds a haven in the dry tinder of rottenness, and, fanned by the breeze, bursts into a tiny flickering flame. This kindles fresh fuel, throws out new sparks to fire the tangled, shrivelled undergrowth, and then, with crackle and roar, the fire is away, all devouring, until a change of wind, want of fuel, or a well-engineered cut, coupled with efficient beating, sets a limit to its devastating progress.

Now, in all the processes of combustion, the amount of oxygen available is a factor of decisive importance. Indeed, oxygen has been very ably called the "Soul of Fire," for, without oxygen, fire cannot exist. When a fire occurs at or near a gasworks, most of the newspapers enlarge on how the "awful" danger of an explosion of the gasholders—so often erroneously termed gasometers—was overcome. All this is mere newspaper padding. If a person were able to enter a gasholder containing ordinary coal gas (a complex mixture of hydrogen, methane, hydrocarbons, nitrogen, and carbon monoxide), taking with him a lighted torch, the flame of the torch would die out, and incidentally he would too, for there is no oxygen in the gas to support either the combustion of the torch, or the process of respiration, which, after all, is only another form of slow combustion.

The above emphasises the previous remarks upon the importance of restricting the supply of oxygen at the seat of any fire.

In 1921 the author was consulted as to the cause of several fires that had occurred in stores containing bags, known as "Hessian Bags," the fibres of which in manufacture had been treated with grease. Two tests were made, with the following result:—

The first with 25 damped bags placed in the middle of a large stack and the temperature taken each day at the face of the stack and by means of a thermometer passed through a tube to the interior of the stack.

Day, - -	1	2	3	4	5	6	7	8	9
Face of Stack,	°F. 64 °C. 17·7	64 17·7	65 18·3	65 18 3	64 17·7	63 17·2	64 17·7	65 18 3	65 18·3
Inside, - -	°F. 68 °C. 20	75 23 8	100 37·7	112 44·4	120 48 8	120 48 8	120 48 8	120 48 8	115 46·1

Day, - -	10	11	12	13	14	15	16	17
Face of Stack, -	°F. 64 C. 17 7	64 17·7	64 17·7	65 18 3	65 18 3	66 18·8	63 17·3	63 17 3
Inside, - -	F. 90 °C. 32·2	94 34·4	86 30	84 28·8	80 26 6	78 25·5	72 22·2	72 22·2

The second test was with 100 damped bags in the middle of the stack—

Day, - -	1	2	3	4	5	6	7
Face of Stack,	°F. 61 °C. 16·1	61 16·1	61 16·1	62 16·6	62 16·6	64 17·7	65 18·3
Inside, - -	°F. 60 °C. 15·5	94 34·4	108 42·2	119 48·3	129 53·8	130 54·4	130 54·4

Day, - -	8	9	10	11	12	13
Face of Stack, -	°F. 64 °C. 17·7	64 17·7	62 16·6	62 16·6	62 16·6	61 16·1
Inside, - -	°F. 124 °C. 51·1	124 51·1	120 48·8	116 46·6	112 44·4	108 42·2

From the above it may be surmised that the rise of temperature in each case was due to fermentation (bacteria), and the gradual reduction of the temperature was owing to either death of the bacteria or to the sacks being

so closely packed that the oxygen in the air could not reach the heated portion, and thus carry on the chemical action (oxidisation) which had commenced until the point of ignition was reached (see p. 141).

If in making hay the cut grass be thoroughly air-dried by exposure to the heat of the sun and air, the germs which are in it will be mostly sterilised, and the moisture reduced to a point at which they are unable to set up fermentation processes. If the hay after being once properly made gets wet the stack may go mouldy, but the more dangerous process of fermentation is so checked that a temperature likely to reach the ignition point of the stored hay is never attained. If, on the other hand, the hay has been made into a large stack whilst still containing a large proportion of the original moisture, the germs of fermentation will still be present in large numbers, and when the stack is made fermentation will start, and this being an oxidising process will give rise to heat. This heat is kept in by the surrounding mass of hay, which is an excellent non-conductor, and soon reaches a dangerously high temperature, and in many cases where actual ignition has not taken place, on cutting trusses out from the stack it has been found that some of the hay is practically carbonised, and had air gained access to it whilst still at the temperature that caused the charring, ignition of the whole stack would have followed.

The above explains why in mountainous and wet localities farm produce is gathered into small conical heaps to complete the drying before being collected into the large stacks.

The processes and conditions which may incite to spontaneous heating or spontaneous ignition, taken in the widest sense, are :—

1. Moisture.	Predominantly in the case of agricultural products, fodder, manures.
2. Bacterial activity.	
3. Germination.	
4. Storage in large heaps.	Agricultural products, coal, tobacco, oleaginous substances.
5. Protracted drying.	Wood, organic substances.
6. Contains sulphur.	Lampblack, coal.
7. Contains finely divided carbon.	Metallic sulphides.
8. Contains fat or oil.	Organic substances, fibres, colours (paint), clothing.
9. Occlusion of oxygen.	Coal, etc., metals.
10. Absorption of moisture.	Quicklime, potassium, sodium, carbides.
11. Fineness of division.	Metals, bronzes, varieties of dust, fats, oils.
12. Recent calcination.	Carbonised substances, metallic powders, metallic sulphides, lampblack.
13. Exposure to the sun.	Phosphorus in fragments, oxyhydrogen gas.
14. Concentration of the sun's rays (burning glasses, lenses, glass bricks).	All readily ignitable substances.
15. Friction, pressure, shock, fall.	Numerous detonating explosive substances (spontaneous ignition being here generally modified into explosion).
16. Electricity, static (sparks).	Resinous bodies, explosive vapour mixtures, as in dry cleaning works, Indiarubber spreading, linoleum works.
17. Air.	Phosphuretted hydrogen and numerous compounds (ethyl, methyl, and prophyl compounds), pyrophorous substances.
18. Contact with spongy metals (platinum black).	Hydrogen gas, oxyhydrogen gas, coal gas.

10

The examples numbered 1 to 9 mostly exhibit slow development (chronic spontaneous ignition), those numbered 10 to 14 progress with moderate rapidity, whilst 15 to 18 are sudden and of explosive character (acute).

The period of development in cases of chronic spontaneous ignition may extend over two or three months; in many cases a good deal depends on the bulk of the stored mass; where this amounts to some hundreds of tons, as in the case of bran, cereals, etc., spontaneous ignition may sometimes take from two to three months before becoming apparent externally.

(11) Pyrophoric Action.—Pyrophoric action, strictly speaking, forms a sub-class of "Spontaneous Combustion," but as it constitutes a common and very frequently entirely overlooked fire risk, it merits special attention. The prototype of this sub-class of "pyrophores" is potassium sulphide, which, when freshly prepared, inflames on exposure to air. Better known to us perhaps is "Platinum Sponge," which, owing to its remarkable powers of absorbing oxygen and hydrogen, glows when exposed to most hydro-carbon gases and some vapours. This substance, in combination with a thin platinum wire, forms the basis of innumerable well-known lighters.

Pyrophoric carbon, a much more widely distributed and unsought-for compound, is our real enemy. The production of this insidious substance in more or less minute and perfected quantities goes on daily in most of our works and many of our homes, and our present immunity from an outbreak of fire due to this pregnant cause is not the result of our foresight or good management, but to the casual absence of the exact conditions necessary for the final awakening into life of this latent danger.

To understand thoroughly the formation of pyrophoric carbon, its nature and its risks, it is first of all necessary to recall to mind the physical action by which certain substances, particularly spongy platinum, carbon in the form of fine coal or charcoal, also dry wood, occlude within their pores many times their own volume of gases, and how this occlusion and condensation generates heat, which, in its turn, favours subsequent chemical action when suitable reagents are present.

Platinum sponge (platinum black) has the property of absorbing 100 times its own volume of oxygen and 300 volumes of hydrogen, consequently it should be kept away from gases, liquids, or substances that may emit oxygen or hydrogen.

We owe to Dr. Von Schwartz the following interesting experiment, which clearly and fairly rapidly demonstrates what goes on much more slowly, but equally surely with minute porous carbon:—

Take two thermometers of equal readings, and wrap some cotton wool round the bulb of one (called A, Fig. 88). Suspend this in a Florence flask, containing 3 to 4 ozs. (0·09 to 0·11 kilo.), of liquid ammonia, so as not actually to touch the ammonia. Suspend the second thermometer (called "B) outside, but not in contact with the flask. The readings of the two thermometers at the outset will be equal, but, in a short time, it will be found that "A" registers an appreciably higher temperature than "B," perhaps 9° F. (5° C.) or 11° F. (6° C.).

Where has this heat come from? No chemical action has taken place. The heat has been entirely generated by the physical action of the condensation of the ammonia gas in the pores of the cotton wool. If "A" is now exposed to the air and the absorbed ammonia gas permitted to

escape, the temperature will again fall, because vaporisation is attended with loss of heat.

(*Note.*—In this experiment external influences such as draughts, radiant heat, etc., must be carefully guarded against.

Keep the flask plugged until it is required. Flask and solution, etc., should be stored and used in the same room to ensure equal temperatures.)

With this knowledge we can now turn to the illuminating researches of that outstanding chemist, the late Prof. Vivian B. Lewes.

He established that one vol. of charcoal at 32° F. (0° C.) and 760 mm. pressure, absorbs :—

Ammonia,	171·7	Volumes.
Cyanogen,	107·5	„
Nitrogen dioxide,	86·3	„
Ethylene,	74·7	„
Nitrogen monoxide,	70·5	„
Phosphuretted hydrogen,	69·1	„
Carbon dioxide,	67·7	„
Carbon monoxide,	21·2	„
Oxygen,	17·9	„
Nitrogen,	15·2	„
Hydrogen,	4·4	„

From these figures, taking for instance the gas oxygen, it will be seen readily how the initial physical action with its generation of heat finally passes to chemical action, increasing rapidly in intensity as the temperature rises. Here is the key to the trouble.

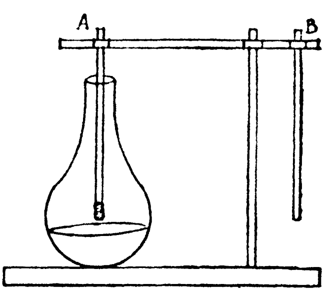


Fig 88.

Now follow the insidious preparation of pyrophoric carbon, which is generally a form of soft charcoal. Ordinary timber exposed to the air at normal temperatures, by its hygroscopic properties, maintains a moisture equilibrium of about 20 per cent.

On exposure to heat, up to 212° F. (100° C.), practically only moisture is expelled, but a few more degrees suffice to slowly drive out hydrocarbons, whilst at 302° F. (150° C.) oxides of carbon commence to appear, and, slightly above this temperature, wood commences to assume a scorched appearance, and to turn brown. A temperature of 483° F. (250° C.) is sufficient to transform wood into a most dangerous form of soft brown charcoal which ignites spontaneously at comparatively low temperatures. Chemical analysis gives the percentage composition of dry, low-temperature charcoal as :—

Temperature.		Carbon.	Hydrogen.	Oxygen.	Ash.
518° F.	270° C.	71·0	4·60	23·00	1·40
686° F.	363° C.	80·1	3·71	14·55	1·64
888° F.	476° C.	85·8	3·13	9·47	1·60
968° F.	519° C.	86·2	3·11	9·11	1·58

Above 518° F. (270° C.) the charcoal gradually loses its more dangerous properties for oxygen.

Now charcoal, when heated, gives up a great part of its occluded gases, and on cooling, again re-absorbs them. Experience teaches that oft-repeated action of this nature enhances the chances of ignition, even when only favoured by a small additional external source of heat. So drastic is this action, that it has been found that if the time of contact is sufficiently long, the temperature of a few degrees above the boiling point of water is sufficient to produce on wood a semi-carbonised film, which will start smouldering if submitted to the slight extra heat from an oil or gas lamp some distance away. This is probably due to the long-continued heat gradually generating hydrocarbons of low " ignition point " which remain in the pores of the semi-charred wood in *intimate contact with the occluded oxygen*.

This demonstrates the unpleasant fact that amongst numerous other sources of low heat, the apparently innocent hot water and steam pipes, not to mention the more dangerous hot air heating arrangements, are fully capable of producing and igniting pyrophoric carbon. It must be remembered that in reasonably lofty buildings heated by hot water, a pressure of 30 lbs. (2 atms.), or a boiling point of 250° F. (121° C.), is quite common, and that with ordinary steam distribution 120 lbs. (8 atms.) or 150 lbs. (10 atms.) 342° F. (172° C.) and 358° F. (181·6° C.) is normal practice.

A case occurred in which charcoal was ignited by the heat of a horizontal flue, which was cool enough for people to walk on.

Steam pipes must be kept clear of combustible material of all kinds and natures. In passing through hollow walls and floors, the steam pipe should be surrounded by a sleeve made of a larger pipe, of a diameter sufficient to ensure a free air space between the steam pipe and the outer pipe. Rodents are fond of making their nests near hot pipes, if well away from observation, with the subsequent burning of the nest.

The materials employed for lagging steam and hot water pipes often contain 25 per cent. and more of combustible material, and therefore present a not inconsiderable risk; but the real danger is constituted by accumulation of dust, as dust, in its state of minute subdivision, lends itself particularly well to the formation of pyrophoric carbon. If on the top of all this, by any chance, a casual drop of oil falls, then conditions are almost ideal for the quickening of the first tiny glow, the fore-runner of fire. The process of carbonisation of dust can be watched in practically any building traversed by hot water or steam pipes, and examples are to be seen in rooms by looking at the wall or ceiling just above the radiator or gas burners. The brown stain is caused by the carbonised dust carried against the wall or ceiling by the currents of hot air. The dust residue remains, and in out-of-the-way corners may accumulate to considerable depth, whereas the heated air or gases readily pass through the porous wall.

The wooden lagging of boilers furnishes an example of wood gradually altered in condition by the application of long-continued, but comparatively low heat. By inspection it will be noted that in some places actual deep charring has taken place, whilst in others only the initial stages of the formation of brown charcoal have been arrived at.

Advantage should be taken of making inspection of old buildings in course of demolition, when examples will be found of pyrophoric carbon due to continued heat at low temperatures. These are more generally found in cases of timber exposed in flues and under hearths. In modern buildings

where central heating is employed and the pipes are enclosed by skirting and wooden lining, it only is a question of time for the woodwork to arrive at the carbon stage.

The obvious precautions to be taken against the risk of fire from pyrophoric action are very simple, namely :—

Cleanliness and the banishment of all carbonaceous substances from the immediate vicinity of sources of heat. The domestic cupboard, through which heating pipes or ducts pass, is a not uncommon lurking place for trouble.

Where the type of construction justifies the extra expense, *efficiently* impregnated wood should be used. The ingredients used for impregnating help to render the wood less susceptible to fire (see Chap. XVIII.).

(12) **Dust Explosion.**—The dust raised either accidentally or in the course of normal industrial working processes of many carbonaceous substances and some metals, not infrequently gives rise to explosions of a most disastrous nature. A few of the principal offenders are :—Coal (indeed practically any form of carbon), celluloid, cork, cotton, flour, rice, starch, sugar, dextrin, rags, wood, tan, grain, bran, malt, hops, wool, tow, fibres, reclaimed rubber, resins, colophony, etc.

The action is primarily attributed to the occlusion of gases, particularly oxygen, by the minute, floating particles of dust. By this property of gas occlusion, dust becomes a real *oxygen carrier*, and as such is capable, in the presence of flame or sparks, of causing the detonation of inflammable vapours and gases without the presence of additional air.

What generally happens is that, when the oxygen-laden dust alone comes into contact with flame, instantaneous partial combustion takes place. Hydrocarbon gases and carbon monoxide are thus formed, which, mixed with the remaining air and ignited by the flaming dust, detonate with extreme violence, blowing out walls, windows, fire-doors, etc., thus very rapidly spreading fire throughout the building. Warm air and the presence of a small percentage of inflammable gas facilitate the explosion and render it more violent. The presence of this inflammable gas may be caused by an escape of coal gas used for lighting (in coal mines by a " blower " of occluded methane), a leak of fuel gas made on the premises, hydrogen or methane given off from damp flour, meal, grain, or metal powders, or electric accumulators.

The amount of dust required is not large, but dryness and minute subdivision are essential. For instance, 10 grammes (⅓ of an ounce) of coal dust with a cubic meter (35 cubic feet) of air give a strong explosion.

Dust clouds have considerable migratory powers, and will roll on across the room and down a stair or lift opening until an unprotected flame is reached, when, if necessary conditions exist, instantaneous ignition and explosion of the whole cloud, right back to its source, will result.

Dust clouds are sometimes produced by purely accidental causes, such as the bursting of a bag or package, but more often by the processes of grinding, screening, cleaning, mechanical transportation, etc., and the casting off of a driving belt. The process of grinding is particularly dangerous on account of the ease with which sparks can be produced if by chance some hard foreign body has found its way into the material in course of treatment. To diminish this danger magnetic separators are frequently installed on the

inlet of these machines, or, whenever possible, the grinding is done wet. In the description of the disastrous fire at the Quaker Oats Mill, Canada (see B.F.P.C. Red Book, No. 225), a good example of the dangers of dust was furnished. Another instance on a much smaller scale, but quite typical, happened some years ago in London. It is of special interest, because it also demonstrates the possibility of spontaneous ignition of warm dust. A fire broke out on the second floor of a works engaged in the production of wood flour. To get at the seat of the fire it became necessary to clear part of the floor, which was crowded with bags of that substance. As a bag, which was warm, but by no means charred or ignited in any way, was being handed down the fire escape it broke open, allowing its contents to fall. Instantly, on contact with the air, the wood flour burst into a cone of flame some 30 feet (9·1 m.) high, seriously scorching three firemen on the escape.

The counter measures to take against dust explosions are very simple, but have to be enforced rigidly, because workmen rarely comprehend the risks they are running, or through immunity from accident become slack and careless. In the first place thorough ventilation must be insisted on, and where the generation of carbonaceous or metallic dust is inevitable it must be confined by completely enclosing the machines, or removed as formed by suitable aspirators. The dust must not be allowed to settle about the room or building, where it may eventually cause trouble by pyrophoric action, or through any cause rise again as an explosive cloud. If any dust-producing machine has to be opened for examination, the dust must first be allowed to settle, and then only a "safety light" used. By "safety light" is meant a modern well-constructed lamp of the "Davy" type, or preferably a well-protected incandescent lamp of the accumulator type, *arranged so as to preclude the possibility of sparks from the contact breaker* coming in contact with the dust-laden air.

Nowadays machines which are dangerous are frequently fitted with a means of blowing in steam, or with one or more sprinkler heads. These arrangements permit the effective smothering of a small outbreak without the very risky opening up to contact with the air. No sparks or flame-producing machinery, apparatus, or fittings, should be installed in, or be in direct communication with, dusty places. The means of illumination should be of a safety type. Many of the so-called "outside lights" are full of snares, while at the best they are only make-shifts, and should not be tolerated. Whilst on this subject it must be remembered that the "Davy" gauze, although a very good protection, is not absolute; for acute vibration of the air will sometimes suffice to pass the flame through the gauze, similarly flame will pass through the gauze if the latter becomes overheated.

Well installed, double-bulb, incandescent electric lamps are safe *if* kept clean and in good order and condition, and *if* all spark-producing fittings, such as fuses, switches, connectors for portable lights, etc., are duly protected from the weather and placed outside the range of wandering explosive clouds of dust, gas, or vapour.

The serious effect of dust explosions usually occur in climates that are hot and dry for long periods at a time. The United States and Canada provide examples of conditions that lend themselves to disastrous occurrences of this nature. The climate is suitable, and large quantities of corn crops

have to be speedily dealt with. The damage commences with threshing machines. A wheat crop containing from 1 to 35 per cent. of smutted heads is particularly liable to cause explosion and fire. In many cases this is due to the formation of an explosive mixture of smut, dust, and air, and the ignition of this mixture by static electricity during the threshing operations.

Two conditions only are necessary to make these dust particles ignite —sufficient heat and the correct proportion of air to the fine dry dust.

Smut "berries" or "balls," as found in the heads of ripened wheat, contain millions of minute spores or seeds, which as they pass through the machine will readily take fire upon coming into contact with a spark or flame.

Probably the chief source of ignition is due to static or frictional electricity (see p. 154).

Much can be done to remove the grain dust to a safe distance, but it is impossible to prevent its formation, therefore an exhaust fan should be provided to collect and remove smut and dust from the separator, and thus reduce the chance of the formation of an explosive mixture of dust.

Fire extinguishers can also be fitted to threshing machines to confine any fire that should occur in the separator.

The electricity generated in the threshing machines by the friction produced by the rubbing of metallic parts or by the slipping of belts on pulleys can be effectively dealt with, by providing a proper outlet for its escape by connecting wires from all moving parts to a properly grounded wire. Should, however, the electricity accumulate more rapidly than it can be led away, it will discharge through the air to any nearby point, and the resulting sparks will ignite the dust suspended in the air, with explosion and fire as a consequence.

In 1913 the Explosion in Mines Committee published the report of Dr. Wheeler's investigations of the relative inflammabilities of various carbonaceous dusts. He classified dusts as follows:—

1. Dusts which ignite and propagate flame readily, the source of heat required for ignition being comparatively small, for example, a lighted match.

2. Dusts which are readily ignited, but which, for the propagation of flame, require a source of heat of large size and high temperature, such as an electric arc, or of long duration, such as the flame of a Bunsen burner.

3. Dusts which do not appear to be capable of propagating flame under any conditions likely to obtain in a factory, because they do not readily form a cloud in air, or are contaminated with a large quantity of incombustible matter, or the material of which they are composed does not burn rapidly enough.

CLASS 1.

Coal.	Oat husk.
Sugar.	Grain (flour mill).
Starch.	Maize.
Rice meal and sugar refuse.	Grain (grain storage).
Wood flour.	Rape seed.
Cork.	Corn flour.
Malt.	Flour (flour mill).

CLASS 2.

Rice milling.	Grist milling.
Castor oil meal.	Corn meal.
Offal grinding (bran).	Mustard.

CLASS 3.

Spice milling.	Sack cleaning.
Cotton seed.	Rape seed (Russian).
Cotton seed and soya bean.	Grain cleaning.

Evidence tends to show that dust explosions take place in two phases :—

1. Partial combustion to Carbon Monoxide and accessory distillation of the carbonaceous particles.
2. Explosive combustion of the Carbon Monoxide and the gases resulting from the above-mentioned distillation or gasification process.

(13) **Rodents.**—Rats and mice, attracted perhaps by phosphorescence or by the wax, frequently cause matches to ignite by nibbling them.

Fig 89.

Again, they have a peculiar predilection (there is no accounting for taste) for lead and compo pipes, and it has been proved that they have thus caused many dangerous escapes of gas. Water pipes, too, fall victims to their busy teeth.

An instance of a direct attack on electric wires or cables cannot be quoted, but such damage is well within the limits of possibility, more especially with certain unarmoured types of cheap insulation sometimes employed for internal work.

Rats have even been accused of carrying away lumps of greasy waste to form their nests, abandoning their homes when they become too warm for them. There is no doubt that with their almost universal habit of gnawing and nibbling they must be regarded as a source of danger, and this, coupled with their general destructiveness and disease-carrying properties, calls for their resolute and wholesale extermination.

See also p. 148 as to nests near steam pipes.

In February, 1920, a rat was electrocuted. It is very rare that an electrical breakdown is traceable to such a cause as that shown in Fig. 89 from a photograph taken at a large works in the Midlands. One night the power suddenly failed, and a lengthy investigation of the electrical equipment resulted in the finding of the body of a badly burnt rat. The rat, in order to get at the oil, had apparently attempted to walk across the high-tension terminals of an oil-immersed switch, and had thereby started a short-

circuiting current. This current had persisted and formed an arc, with disastrous results to the rat, and also to the main switch. Luckily no inflammable matter was near, and no further fire occurred.

(14) Night Watchmen.—The greatest source of danger provided by the night watchman is dealt with under sub-heading (2), Tobacco and smoking. Furthermore, if men would only learn invariably to close doors behind them, fires would probably be limited in their destructiveness to the room or section in which they originated. Unfortunately the average man will take neither of these simple precautions; therefore it is preferable, whenever possible, to keep night watchmen to the exterior of buildings, and to arrange for numerous glazed inspection holes, by means of which they can obtain an unobstructed view of the interior. The lamp carried is also a source of danger, and should preferably be a closed, safety, electric, accumulator type. Regular rounds should be arranged for, and these should be checked by frequent reliable inspections or by some form of tell-tale clock. The portable variety worked in conjunction with *fixed* but changeable punches, gives the best result for a reasonable expenditure. The diagrams should be changed and inspected daily by a responsible member of the staff. An all-round glazed shelter should be arranged at some central point, where the watchman is to remain when not on his rounds. All keys should be kept there in a locked cabinet with a glass door, which may be broken in the case of emergency. Telephone or alarm bell communication with the fire brigade and staff should also be provided. The men should, at least, be trained in the elements of fire prevention and fire fighting. The best watchman is a good electric fire alarm system if it, in its turn, is duly watched and tested.

(15) Overheating of Bearings, etc.—The unobserved overheating of machinery is a risk, which, with proper attendance and supervision, should never take place, but is not an uncommon cause of fire. Long shafting, bearings hidden from general view or not readily accessible, enclosed bearings, and those working in a dusty or gritty atmosphere, form the most likely sources of trouble. Accumulations of dirt, waste materials, and grease on the shafting, bearings, and brackets, facilitate heating and feed a starting fire. With high-speed machinery, the overheating of a bearing may also result in the fracture of a spindle and a subsequent bad accident due to the flying pieces projected by centrifugal force. With railway rolling-stock, the overheating of a bearing means the possible fracture of an axle, resulting in a general smash up, followed by a fire in the debris, and the burning to death of any unfortunate people who may be pinned down under the wreckage, not to mention the danger from scalding steam escaping from fractured heating apparatus.

A simple and effective preventive measure is to instal all machinery at the start in such a way that it is well illuminated and easily accessible. When choosing machinery careful consideration should be given to the design with reference to the accessibility of the various parts, as this has great influence on eventual safety and general durability. Neglect of these simple and obvious precautions is the direct or indirect cause of 90 per cent. of machinery troubles. Men cannot and should not be expected to go out of their way, and to expose themselves to risk of injury in order to give that close and careful attention, which is all the more necessary when machinery is ill-lit and difficult of access. Define responsibility clearly—

real cleanliness. Mere polish of obvious and exposed surfaces is not cleanliness in fact, and in many cases it is nothing less than a serious waste of time and labour.

The principal of a business should occasionally look into all these matters himself.

That beautiful damaskeened steel rod—mere glittering ornamentation—will always be very much in evidence. It is meant to be looked at. It is only by getting into a boiler suit, and going behind and underneath, that things not prepared for inspection come to light. Then it is that unauthorised time and labour-saving arrangements (some commendable, but mostly not). and surreptitious gas rings for boiling water in places supposed to have safety lighting, are unearthed. Where electrical drives are employed it is an easy matter to form an approximate idea of the condition of machinery by frequently comparing the power absorbed under equal conditions. Fans, particularly aspirator fans, fitted to draw off carbonaceous dust from buildings and thus reduce explosion risk, merit special supervision. By reason of their high speed and enclosed condition amid dust, they are peculiarly prone to cause sparks by attrition of their vanes, not to mention the possibility of the overheating of bearings in the case of the unsuitable inside-bearing type. Instead of being a guarantee of safety, they have become in several cases a cause of disaster.

The crank chambers of modern high-speed engines, whether they be steam, gas, petrol, or heavy oil engines, are filled with oil spray, which consists of fine oil particles and would explode if a spark were formed inside the chamber.

Sparks in crank chambers can be produced by fractures of moving parts or hot bearings, but the vapours are more frequently ignited, in the case of internal combustion engines, by a blow through of the burning charge past broken or jammed piston rings.

The remedy is thorough ventilation of the chamber and the provision of ample and very light explosion doors. In many cases these are made of a stiff type of oil-proof parchment paper.

There are many devices in use to-day to prevent or minimise the effects of overheating, but these devices are palliatives only, and the real remedy lies in careful well-organised working, by which nothing is left to chance.

(16) Static Electricity Generated in Industrial Processes.—The generation of static electricity by simple friction during every-day industrial working, in the presence of inflammable dust clouds, vapours, or gases, constitutes a very grave danger. Effective insulation is caused by dry air. Once the latter is humidified 90 per cent. of the danger disappears. The remainder can be avoided by good earthing. Under dry air conditions electric sparking may be noticed after dusk, from the dry belts to the belt fork. In linoleum factories the friction caused by the shifting of large sheets of this material frequently brings about considerable electrical discharges. Again, in rubber works, the grinding of reclaimed rubber, the milling of rubber with filling compounds, and the friction caused by mechanically spreading very thin layers of rubber on textile fabrics, cause important discharges which occasionally ignite the vapours of the hydrocarbon solvents employed and cause fire. The mechanical kneading of the gelatinised paste of celluloid also occasionally gives rise to sparks. On some of the machines used in

these processes attempts have been made to collect the electricity generated before it attains a dangerous tension. This is done successfully by well-earthed metal brushes with sparking gaps reduced to a minimum. Another precaution that can be easily adopted is the provision of a sufficient amount of humidity in the atmosphere. Experiments have shown that the whole subject is one of the greatest interest, and merits more attention than has been devoted to it up to the present. Every problem of this nature requires separate consideration; but generally, by careful electric bonding, it should be possible to eliminate, or at least considerably reduce, the bulk of these insidious risks. Speed of working is an important factor, and sometimes, by slightly reducing it, troubles disappear.

By reason of its electrical properties that highly inflammable volatile, liquid hydrocarbon Benzene constitutes a whole series of fire risks in itself. For instance, the washing or so-called "dry cleaning" of textile fabrics in benzene is sufficient, under favourable conditions, to electrify the fabrics positively and the benzene negatively. As benzene is a bad conductor, the electricity generated accumulates until sufficient tension is set up to cause sparks, which ignite the vapours and give rise to the popular belief that benzene is spontaneously inflammable. Centrifugal drying machines used in this connection are particularly dangerous. Dr. Richter attributes these phenomena primarily to the electricity of the human body, which is transmitted to the fabrics. He also points out that warmth, and moisture of the air (70 per cent. saturation) enormously reduce the risk of sparking. Under favourable conditions of low temperature and dry air, the slight friction of benzene against the neck of a carboy from which it is being poured, is sufficient to cause a spark and ignition. Ether shares the dangerous properties of benzene, with the aggravation that its vapours are even more readily inflammable.

The heavier the spirit (*i.e.*, heavier sp. gr.) the less dangerous from a fire standpoint, subject, of course, to certain limitations.

The following account is given of a fire which occurred in a continental theatre on 29th June, 1925:

The head wig maker and a few assistants were washing wigs in a bucket of petrol. The wigs were of long hair, and held together by a small iron wire.

The danger was known, and, therefore, the washing took place during the day time, in the Firemen's lodge and under the Fireman's superintendence.

For no apparent reason a flame suddenly flashed out of the bucket and set the room alight. The fireman and two of the assistants escaped with severe burns, but the head wig maker and one assistant were burned to death.

It was proved that there was not any direct or indirect fire or light near.

The only explanation the authorities can give, is that by rubbing the hair in petrol, static electricity was generated.

(17) **Workmen employed on repairs.**—Not infrequently workmen called in for repairs leave indelible traces behind them. These may even amount to the total destruction of some great and beautiful, perhaps irreplaceable building. There are special risks when the nature of the repairs entails the use of heat in some form. The overheating of a soldered copper joint, the autogenous soldering of lead overlying old, bone-dry timber, the spilling of overheated lead, the careless lighting up or placing of a soldering lamp near combustible matter, a forgotten brazier, to say nothing of smoking in out of the way corners, are but a few of the every day incidents which may lead to Fire.

These fires generally commence in out of the way places, such as roofs, towers, organ lofts, etc., and in this country have been responsible for the destruction of many fine manors. Numerous examples could be given, mostly of churches and other public buildings.

Workmen, and particularly unknown workmen, should always be properly supervised, more especially when employed in unfrequented places, for damage is all too easily done by common carelessness.

(18) **Lightning.**—The first essential in dealing with a problem of this kind is obviously by a thorough knowledge of the subject to be able to detect and dispel the errors which have been so generally committed.

How many people will tell you lightning is an electrical discharge, that they have seen it, and in the next breath admit that no one has ever seen an electric current but only the attendant circumstances? No one ever really sees lightning, but only the incandescence in the atmosphere caused by the velocity of the current and the resistance of the air.

Many strange ideas are prevalent as to the occurrence of lightning. Some people will tell you that one should cover up bright objects when a storm is in progress in order not to attract the lightning. Other people will shut themselves up in all manner of queer places. But all these proceedings are unnecessary and only emphasise the old philosophical axiom that where knowledge fails superstition creeps in. Lightning is an electric current. It occurs in periods when the atmosphere at different places is under dissimilar conditions, which give rise to a cloudy state of the sky. These clouds are usually very cold, and as they travel by the directing influence of wind, set up when the atmosphere of two contiguous districts mingle—*i.e.*, when the hot air rises and allows the colder air to flow in—they pass over areas of intense atmospheric rarefication, and thus storms and lightning discharges occur until the temperature of the district is lowered, during which operation the moisture in the atmosphere is condensed and descends as rain.

Thunderstorms are of two types, "Cyclonic"—such as occur mostly in the winter months and generally produce only a few, but very severe flashes —and "Heat"—such as occur in the summer months and often produce a brilliant display of flashes, which often appear more severe than they really are.

The "Cyclonic" storms generally travel at a great height and pass over the land (frequently in a straight line) irrespective of its contour. "Heat" storms are generally at a lower altitude, and are apt to follow the course of valleys.

Apart from the well-known and recognised occurrence of storms in well-wooded districts, statistics show that towns more often suffer than open country. This is probably because the atmosphere over the towns, being laden with particles of carbon from smoke, offers less resistance to the electrical discharges.

As electric currents take the line of least resistance, it is necessary to provide on buildings lines of less resistance than the materials of which such buildings are constructed, along which the lightning may pass, instead of rushing, with perhaps disastrous effect, through the buildings themselves. Metal is a good conductor, so lines of metal are applied as lightning conductors, and, if erected on scientific principles, they should afford adequate protection.

Lightning in this country is estimated to cause from £50,000 to £100,000 damage per annum, usually divided up into a number of comparatively small items. This damage is generally done to unprotected buildings, although failures of protective installations (due to faulty conception or maintenance) occasionally arise. When a fire is started by lightning it is generally due to the ignition of escaping gas or of some readily inflammable material. Generally speaking, however, fire does not break out, but a great deal of damage can be done solely by the lightning. When it is remembered that lightning flashes may be anything up to a mile or more in length, and that the calculated tension of such a flash is somewhere about 3,500,000 volts, and, further, that a severe storm may mean 10,000 and upwards of such flashes, it becomes evident that properly designed lightning conductor systems are not only desirable but imperative. The principal object of a good conductor system is not to conduct away violent discharges (it does that occasionally), but to act as a preventive by assisting to maintain the equilibrium between atmospheric and terrestrial electricity. Discharges of lightning in an upward direction are not unknown, and on mountain crests pale electrical discharges can sometimes be seen streaming from one's ice-axe. In the Plains of Lombardy, an area subject to very heavy thunderstorms, one can admire magnificent brush discharges—the so-called "Fires of Saint Elmo"—from buildings fitted with conductors or from structures such as large gasholders, etc. There is nothing mysterious about lightning, and all its so-called "vagaries" are due to the fact that it invariably takes the *real* line of least resistance, and consequently will discharge at any angle —not merely vertically, but also in a diagonal direction.

This real line of least resistance may be partly through a lightning conductor and partly through piping or some other metallic structure, for it does not follow that, because a conductor is erected, the lightning will follow it if an easier path exists through some other line of metal. Every building to be protected should be dealt with separately by persons who have made this their special study.

Few structures can be protected by one conductor. Generally a number are necessary, and they must be well connected, thoroughly earthed, and, in addition, efficiently bonded to any metal, roof guttering, and piping which may exist. The question of the possibility of lightning finding its way through secondary metallic paths such as gas and water pipes is one requiring much consideration. If these are bonded to the conductor system, the bonding must be done thoroughly, and a clear, continuous road to a good earth provided. If they are not bonded to the conductor system then the system must be kept well away from them—never less than 4 feet. It should be borne in mind that the best insulation against lightning that we have at our disposal is cold, dry air. Warm air is less resistent, probably on account of its minor density, and it is for this reason that groupings of cattle or persons in the open (which produce an upward current of warm air derived from the warmth of their bodies), sometimes receive the discharge.

Protection against lightning is by no means a simple matter. Most buildings are a mass of inefficient conductors in the form of gas and water pipes, electric wires, and isolated metalwork. Before conductors are applied the scheme of protection will require careful study or the current may be diverted from an intended to an unintended line of metal, and damage result.

On one occasion lightning was found to have caused an outbreak of fire in the belfry of a lofty church tower. On investigating the circumstances, it was discovered that one of the staples used for fixing the copper conductor had been driven into a joint in the stonework, at a point exactly opposite to a similar staple holding a " compo " gas pipe on the inside staircase wall. The current had passed for 200 feet down the copper tape, and had then encountered this short cut, which it followed, fusing the pipe. A portion at least of the current had followed the gas pipe down the stairs, setting fire to a small gas meter and burning the wood near by. Want of fuel, in the form of combustible material, had, however, prevented any serious damage being done.

When fires occur there is nothing to distinguish them from ordinary outbreaks, and the course to be pursued need not differ from that followed at ordinary fires. In these cases there is, perhaps, greater risk of a fall of masonry or brickwork which has become dislodged or loosened at an early stage of the fire.

It must be remembered that every building damaged by lightning may not have combustible materials in, or about, it. In fact, it may be estimated that approximately only 20 per cent. of the buildings damaged are also set on fire.

When lightning passes down a wall, church spire, etc., the heat is so intense that the moisture, found in all exposed materials, is converted in the smallest fraction of a second, into steam,* this steam is created so quickly that it acts as an explosive and with great violence blows out the part heated, thus causing a gap in or displacement of the materials. If the centre of gravity of the mass remains in its original position the structure may stand although damaged, but if the centre of gravity is removed, a collapse may be expected.

In the case of a tree, the conversion of the sap into steam shatters the trunk.

Those interested in the subject are recommended to read " Lightning and the Churches," by Alfred Hands, F.R.M.S.

Suggested Rules for the Supply and Erection of Lightning Conductors.

Conductor.—Each main conductor should consist of annealed copper tape $\frac{3}{4}$ inch × $\frac{1}{8}$ inch, having a conductivity of not less than 98 per cent. of pure copper, manufactured and supplied in continuous lengths up to 300 feet, without joints. Branches and connections to roof metals should be of copper tape $\frac{3}{4}$ inch × $\frac{1}{8}$ inch. The conductor should be erected plumb, or horizontal; all sharp angles should be avoided. Provision should be made for expansion and contraction of the copper tape.

Joints.—Where straight joints are necessary, they should be not less than 2 inches in length firmly riveted with five copper rivets, the holes for rivets drilled *in situ*; thoroughly soldered.

Earth Plates.—The earth plates should be of copper 3 feet × 3 feet by No. 16 gauge, to one of which each conductor should be riveted and soldered

* As has been mentioned, 1 cubic inch of water occupies 1,642 cubic inches when converted into steam.

the full length of the plate; the joints should be thoroughly washed free of acid, and protected by a thick coat of tar.

Wood Charcoal, to make a well-rammed bed 6 inches below and 6 inches above the earth plates, should be clean and free from traces of sulphur.

Tests on Completion.—The earth connection of each conductor should be tested and should have a resistance not greater than 5 ohms between it and the nearest available water pipes or other good earth connections.

Holdfasts.—Holdfasts consisting of clips of copper or gun-metal should fit the conductor so that its weight would be evenly distributed; placed at 4-feet intervals on masonry work; secured by round-headed jagged copper nails; the masonry and all brickwork plugged, for fixings, with lead.

Other Methods of Fixing.—The copper tape when run on lead roofing should be secured by clips soldered to the roofing at distances not exceeding 5 feet, and must not be nailed to such roofing; on asphalt roofs it should be dressed down flat and not otherwise fixed; on woodwork, fixed where possible with holdfasts and nails or screws when these can be used without injury.

Points.—(*a*) Multiple-pointed rods composed of copper tube ¾-inch internal diameter and 1 inch external diameter, furnished at the top with a boss, one 10-inch centre point, and four subsidiary points each 3½ inches long. (*b*) Single-pointed rods consisting of solid copper of ½ inch diameter with suitable copper saddles. The lower ends of the rods should be fitted with flat coupling pieces, riveted and soldered to the main tape.

Height above Building.—Multiple-pointed rods extending at least 4 feet, and single-pointed rods at least 1 foot 6 inches above the highest portion of the building to which the conductor is fixed.

Connections to Metal Work.—Connections should be made from the conductors to the rain-water gutters and to all exposed metal work on roof, or within 4 feet of the copper tape; such connections being made by copper tape specified in the first clause above and substantially joined to it.

Protection.—Each conductor should be protected by a substantial hard-wood casing not less than 1 inch in thickness for a height of 8 feet from the ground, and for a suitable length in any other part of the run where it might be handled or subjected to any mechanical injury or theft. The wood casing should be securely fixed and subsequently painted with three coats of oil paint. The wood casing should be well made and securely fixed.

Test Clamp.—When there are several conductors on a building inter-connected over the roof, each conductor should be provided with a clamp for testing purposes fixed immediately above the wood casing. The clamp being of gun-metal provided with two set screws, so that the tapes are closely and effectively pressed together.

(19) **Storage.**—**Coal** is unavoidably stored in relatively large quantities, but the bulk should be divided as much as practicable, and kept well under observation. When overheating is noticed, the affected section should be at once located, and, if not too late, used up, or spread out in very thin layers to cool by conduction and convection. This last can only be done effectively at the very early stages.

In dealing with coal, especially when abroad, or at a distance from the coalfields, it is sometimes impossible to subdivide efficiently the large stocks

it is necessary to hold. Stocks up to 130,000 tons have often to be handled in a comparatively limited space. In cases like these, redoubled vigilance is required, as the only hope is to detect trouble in time. To enable this to be done, arrange for the preparation and placing of hundreds of ¾-inch (0·02 m.) iron pipes, closed at the bottom end and open at the top. These should be driven down through the coal heaps and left projecting 2 or 3 feet.

They should be set out at not more than 30 feet (9·14 m.) centres, and plotted on a rough plan of the heaps. The temperature inside the pipes should be taken once a week at a level about 3 feet (1 m.) above the ground by means of a maximum thermometer slung on the end of a line. The readings should then be plotted on the plans and any rise of temperature very carefully noted. A temperature of 75° F. (24° C.) * should be spotted in red, there-

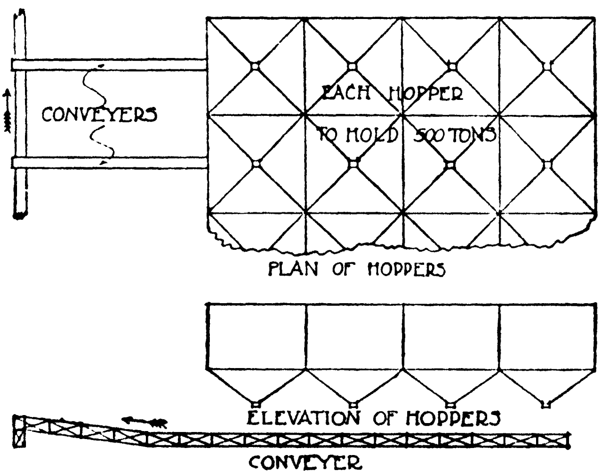


Fig. 90.

after the temperature should be read daily. In this country ¾ or ½-inch solid rods are often used. These have to be pulled up and tested by the palm of the hand. This system gives quite good results when worked by experienced men, but cannot be considered a scientific solution of the problem. At 135-140° F. (58-60° C.) the coal must be got out forthwith and used. Where the necessary capital outlay is permissible, the arrangement of ferro-concrete storage bins, or hoppers and belt conveyors (see Fig. 90) is ideal, as it permits coal to be taken from any affected point with the minimum of labour.

Needless to say this arrangement, with slight modifications, can be successfully employed for grain and other materials.

It was suggested in 1892 by the late Professor Vivian B. Lewes that carbon dioxide might be used with advantage at bulk coal fires in confined places, and he thought that by compressing the gas to a liquid state and storing

* Fire Offices Regulations.

it in steel vessels, it could be easily conveyed to any place required and liberated into tubes laid in the store, or forced down the temperature pipes. A considerable amount of force is required to properly disperse gas in a heap of coal. It has been advocated that pouring down the pipes crude sulphuric acid followed by an alkali solution would be effective, this might act over a very limited area.

The best policy is to remove the coal before the temperature of ignition is reached.

Steel tanks, circular in form, are sometimes constructed for coal storage, some even exceeding a capacity of 2,000 tons (2,032 tonne). In the case of large tanks it has been found necessary, in order to prevent abrasion and the corrosive action of the sulphur in the coal, to line the tanks with material that will resist such action. One method of lining is to provide numerous iron lugs round the inside of the tank, to which are fixed vertical rods from top to bottom. Upon the rods wire cloth is laid, leaving a space of about ¾ inch (0·02 m.) from the face of the tank. A special hydrated cement grout is then projected by compressed air upon and through the mesh. When one layer has set, the process is repeated until a total thickness of 5 inches (·127 m.) is attained.

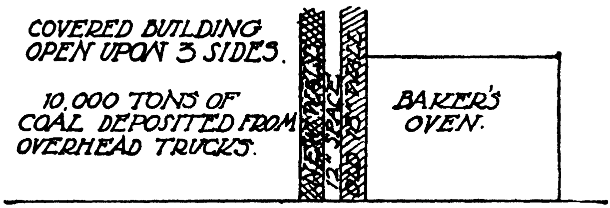


Fig. 91.

In storing large quantities on the heap method, it is seldom possible to allot particular spots to particular coals, but if it is possible to do so, then the soft, fine, bituminous coals, which are dangerous, should be separated from the hard, lumpy varieties which are comparatively safe. A closer watch can then be kept, and arrangements made to get at the dangerous varieties easily, especially if travelling cranes and grabs are available, and plenty of good roads of access are provided.

It should be remembered, as before mentioned, that the application of even a small source of external heat often has serious results. This was particularly well brought to notice some years ago by a series of fires in one of the coal sheds in a large gas-works. This shed was a covered building, open on three sides, and was filled by means of Decauville trucks fed from an overhead broad-gauge siding. The shed held 10,000 tons.

Complaints were being made about the "bad" coals, but when it was found that an area—the most un-get-at-able spot in the shed—heated up time after time, it became evident that there was something beyond the coals at fault. On examination it was disclosed that a neighbouring baker had built an intermittent reverberatory baker's oven against the party wall. From this oven a very small quantity of heat, little more than a trace, passed through the 18-inch (0·46 m.) wall for a few hours daily. This

insignificant source of heat was isolated by building a short length of new wall as a shield, leaving an air space of 1 foot (0·3 m.) wide behind it open at the top as shown in Fig. 91. This proved effective, and the trouble ceased.

Experience teaches that the height of the heap of slack has a considerable influence on its heating. A heap should not be more than 13 feet (4 m.), and is better at about 10 feet (3 m.) in height. The zone of maximum temperature is always to be found about 3 feet (1 m.) above ground level.

Vertical section of a coal heap (see Fig. 92).

Now examine what happens in a coal heap. The moist mass of finely subdivided carbon commences to oxidise. This reaction generates heat throughout the mass. The heat generated near the surface and near the ground readily escapes as soon as formed; but, in the heart of the mass, heat is generated faster than it is dissipated, and, therefore, the temperature continues to rise. As the temperature rises so the rapidity of combination between carbon and oxygen increases, until ignition point is reached, and then fire breaks out. This will happen with any mass of finely subdivided carbonaceous matter. It is merely a question of addition and subtraction of calories. If heat is generated faster than it is dissipated, it will eventually arrive at ignition point and fire will result. In the case of a coal heap, the

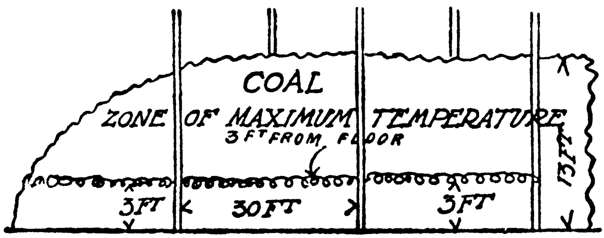


Fig 92.

heat generated commences to pass through the overlying coal and the resultant hydrocarbon gases and vapours slowly begin to escape in yellowish wreaths from the surface, giving rise to a sickly odour, quite unmistakeable once it has been smelt. Later, these gases ignite, and unless efficient mechanical means of handling the burning mass is at hand, or there is plenty of open space to which the coal can be carted away from the affected area, the whole heap will be involved. *Once the fire is started in a large heap it is almost useless to attempt to extinguish it with water.* Nothing short of submersion would be of any use—that is to say, a great cooling action coupled with the complete exclusion of free oxygen.

If large volumes of water are thrown on a burning mass of coal or coke, it will drive the hot gases of combustion laterally into the heap and so bring new areas up to "ignition point," and also generate the poisonous and explosive carbon monoxide gas. Some engineers maintain that the ventilation of the coal heaps should prevent fires; but in practice it rarely does, as it is difficult to provide sufficient, particularly in large stocks. In practice inadequate ventilation of a large heap, by creating a more active air circulation than could normally exist in the compacted mass, supplies a larger volume of oxygen to the zone of reaction, and thus makes matters worse.

For coal in ships' bunkers, see Ship Fires, Chapter V.

The Storage of Gunpowder and the regulations for premises registered for the keeping of mixed explosives are governed by the orders made under the Explosives Act, 1875.

These orders may vary in different localities, therefore the local by-laws and orders should be consulted and reference made to the Act itself and to the various orders made under it or to the "Guide Book to the Explosives Act, 1875," which is obtainable through any bookseller. The following may be taken as the main provisions :—

The premises must be registered with the local authority. Fifty lbs. (23 kg.) of gunpowder is the maximum quantity allowed to be kept in a dwelling-house, but 100 lbs. (46 kg.) may be kept in a fire-proof safe in a dwelling-house or other building, provided that such safe has no exposed iron or steel in its interior. 200 lbs. may be kept in a substantial building exclusively appropriated for the purpose, or in a fire-proof safe, when such building or safe is detached from any dwelling-house; is at a sufficient distance (50 feet (15 m.) is considered ample) from any public street, passage, or place, and has no exposed iron or steel within it. The total amount of gunpowder kept upon any registered premises must not exceed 200 lbs. (91 kg.).

Highly inflammable and explosive substances must not be kept near the gunpowder.

"All gunpowder exceeding One Pound in amount shall be kept in a substantial case, bag, canister, or other receptacle made and closed so as to prevent the gunpowder from escaping." Accordingly no package containing more than One Pound must be opened on registered premises. If, therefore, loose gunpowder is required to be retailed in quantities under 1 lb. (0·45 kg.), it should be received from the makers in 1-lb. canisters or packages for the purpose. For retailing in quantities above 1 lb. (0·45 kg.) the dealer should obtain packages or kegs of the required quantities for selling unopened.

Due precaution must be taken for the prevention of accidents by fire or explosion in the premises, and for preventing unauthorised persons having access to the gunpowder.

Regulations for the Sale of Gunpowder.—Gunpowder may not be sold to any child apparently under the age of 13 years.

All canisters or packages containing more than 1 lb. (0·45 kg.) must, when exposed for sale or sold, be conspicuously labelled "Gunpowder."

Packing and Conveyance of Gunpowder.—The occupier of the registered permises must conform to the provisions relating to the packing and conveyance of gunpowder. These provisions are set forth in Orders of the Secretary of State (Nos. 4 and 7), relating respectively to the conveyance of explosives and to the packing of explosives for conveyance. (See Guide to the Explosives Act.)

Registration.—The registration of premises is valid only for the person registered, and must be renewed annually, with the Local Authority.

Authorised explosives other than gunpowder are known as mixed explosives. This term covers all kinds other than gunpowder, whether mixed with it or not.

The most dangerous class of these is the 5th or Fulminate class, which

includes any chemical or mechanical compounds peculiarly susceptible to detonation, and which may, therefore, be employed in percussion caps or other appliances for developing detonation.

The class consists of two divisions :—

(*a*) Compounds such as the fulminates of silver and mercury, and any preparation consisting of a mixture of a chlorate with phosphorus or a mixture of a chlorate with sulphur with or without carbonaceous matter; and

(*b*) Compounds comprising such substances as the chloride and the iodide of nitrogen, fulminating gold and silver, diazobenzol, and the nitrate of diazobenzol.

Class 6, or the Ammunition class of mixed explosives, has two divisions, of which one comprises ammunition which does not contain its own means of ignition, such as cartridges, charges for cannon, shells, mines, blasting apparatus, fuses, firing tubes and war rockets, whilst another includes fog signals, percussion caps, safety cartridges, and fuses.

Police certificate necessary for keeping certain explosives :—

"There shall not be kept on any premises registered for the keeping of mixed explosives any explosive (other than gunpowder, small-arm nitro-compound, safety cartridges made with gunpowder or with small-arm nitro-compound, cartridges or charges for cannon or blasting made with gunpowder, and not containing within themselves their own means of ignition, percussion caps, safety fuse, or fireworks) except in pursuance of a certificate granted by the chief of police, that the occupier of the registered premises is a fit person to keep, during the continuance of the certificate, such of the explosives allowed to be kept on registered premises, as are specified in the certificate."

Explosives may not be hawked, sold or exposed for sale in any highway, street, public thoroughfare or public place, or sold to any child apparently under the age of 13 years.

The packing and conveyance of explosives must conform to the provisions contained in the Order of the Secretary of State (see above).

The occupier of registered premises in which an accident by explosion or by fire occurs which causes loss of life or personal injury, must at once notify the Secretary of State.

Explosives must not be deposited in any receptacle or place for refuse, or handed to any person employed in the removal of refuse, unless due and proper notice has previously been given to the person whose duty it is to remove the refuse.

Explosives must not be conveyed in any carriage or boat appropriated for the removal of refuse.

Any person or persons concerned in the depositing of any explosive with refuse contrary to the Act, be he the owner of the carriage or boat, the person in charge of such conveyance, or the person owning the explosive, shall be liable to a fine of £10 to £20.

Fireworks for sale can be kept upon premises registered for the purpose.

Fireworks, not exceeding the quantity set out under Mode B in table below, may be kept in a dwelling-house or shop in a properly labelled, closed box, cupboard, or other receptacle that will protect them from accident from

fire, but they may **not** be kept in a fireproof safe. "Shop Goods" may be kept in a glass show case, provided that such case is not placed in the shop window.

Fireworks in larger quantities, but not exceeding the maximum quantity set out under Mode A in table below, must be kept in a Magazine, substantially built of brick, stone, iron, or concrete, detached from any dwelling-house, and at a safe distance from any public street, passage, or place. Such Magazine must be kept securely fastened and must have no exposed iron or steel.

The quantities of Fireworks that may be kept on registered premises are as follows:—

In Mode A.

The safer forms of fireworks known as "Shop Goods,"	400 lbs.
or	
Other fireworks,	200 „

In Mode B.

The safer forms of fireworks known as "Shop Goods,"	100 lbs.
or	
Other fireworks,	50 „

Note.—Where both "Shop Goods" and other fireworks are kept, two pounds of the former are considered to be equivalent to one pound of the latter.

Fireworks may be kept in Mode A and Mode B, but the total quantity must not exceed the quantity set out under Mode A.

Nothing else may be in the receptacle or the Magazine with the Fireworks.

Inflammable articles may not be kept near the Fireworks, and precautions must be taken to prevent accidents.

Fireworks must not be sold to children apparently under the age of 13 years.

Fireworks exceeding 5 lbs. in weight exposed for sale, or sold, must be in a substantial case, bag, canister, or other receptacle, and must be conspicuously labelled "Fireworks," "Explosive."

The weight of Fireworks means the weight of the articles complete, and includes woodwork and casing as well as the explosive contained therein.

The following lists of Fireworks show those which are included within the description of "Shop Goods" and those which are not:—

The expression "Shop Goods" includes:—

Coloured fires and lights.	Fountains.
Balloon fireworks.	Amorces.
Roman Candles.	Throwdowns. } Toy Fireworks.
Wheels.	Crackshots. } Toy Fireworks.
Bouquets.	Squibs.
Saxons.	Electric Sparklers.
Blue Devils.	Prince of Wales' Feathers.

Black Jacks.	Lances.
Snakes.	Crackers.
Golden Rain.	Catherine Wheels.
Portfires or Blue Candles.	Scintillettes.
Starlights.	Lightning Paper in Envelopes.
Tourbillions.	Mines. } Other than those specified below as excluded,
Suns.	Maroons. }
Devil-Among-Tailors.	Rockets. }
Gerbs.	Jack-in-the-Boxes. }
Flower Pots.	

and other similar Fireworks which are not liable to explode violently.

The said expression "Shop Goods" does **not** include :—

Socket Distress Signals.	Maroon Rockets.
Socket Light Signals.	Guncotton Rockets.
Sound Socket Signals.	Flights of Rockets.
Shells.	Mines } Above 2 lbs. gross weight.
Aerial Maroons.	Jack-in-the-Boxes }

Feu de Joie, above 2 lbs. gross weight.
Maroons exceeding 4 ozs. gross weight.
Chinese Crackers exceeding 4 inches in length,

or any Firework (other than a toy Firework) containing its own means of ignition, whether or not named in the foregoing list of "Shop Goods," or any Firework liable to explode violently.

(*Note.*—Bengal Matches are not held to be fireworks, and may not be kept near fireworks.)

The registration of premises is valid only for the person registered, and must be renewed annually.

The Storage of Low-flash Petroleum [*i.e.*, having a flash point below 73° F. (23° C.)], and its distillates is governed by the Petroleum Acts, 1871 to 1881, and regulations made by the Secretary of State under the Locomotives on Highways Act, 1896. Persons interested should obtain full particulars of these requirements before incurring any expense in providing places for its storage.*

The main idea is to isolate the stores so that, in the event of leakage or fire, the outbreak may be easily controlled.

Petroleum to which the Petroleum Acts apply means any rock oil, Rangoon oil, or Burmah oil; oil made from petroleum, coal, schist, shale, peat, or other bituminous substance; and any products of petroleum or any of the above-mentioned oils, which, when tested in the prescribed manner, give off an inflammable vapour at a temperature of less than 73° F. (23° C.).

This definition thus includes benzine, benzol, carburine, gasoline, motor spirit, naphtha, pentane, petrol: and these and similar substances are termed "Petroleum Spirit."

Any compositions or mixtures containing Petroleum Spirit are termed

* Paraffin or Petroleum oils, such as are commonly used in domestic lamps, do not flash below 73° F. (23° C.).

"Petroleum Mixtures," and include india-rubber solution, some varnishes, quick-drying paints, etc.

Seven days after importation, all vessels containing Petroleum Spirit must be labelled in conspicuous characters with the nature of their contents, and the name and address of the owner, sender or vendor, with the addition, in the case of Petroleum Spirit, of the words "highly inflammable," and, in the cases of Petroleum Mixtures of the words "Petroleum Mixture, giving off an inflammable heavy vapour," "Not to be exposed near a flame."

Petroleum can only be kept in pursuance of a licence granted by the Local Authority, except as follows :—

(*a*) Not exceeding 3 gallons may be kept for private use or for sale in separate glass, earthenware, or metal vessels securely stopped, each of which must not contain more than one pint.

(*b*) In the case of Petroleum Mixtures, solid, or otherwise unsuitable to be measured by liquid measure, not exceeding 30 lbs. may be kept in separate sealed packages or vessels each containing not more than 1 lb.

(*c*) When it is kept or used for the purpose of vehicles such as motor cars, motor cycles, etc., legally known as "light locomotives," in accordance with the Regulations as to Petroleum made by the Secretary of State.

Licences are required for larger quantities than 3 gallons (13·6 l.), and the Local Authority may require a ground plan to be furnished, showing the buildings within 50 feet (15 m.) of the place where it is proposed to keep or use petroleum.

Petroleum spirit should, whenever possible, be stored in the following method if above ground :—

In a concrete, stone, brick, or iron store, the lower part so constructed as to form a well capable of receiving, in case of accident, all the Petroleum contained in the store. The store should have ample floor area so as to avoid making the well too deep. The store must be ventilated sufficiently, at high and low levels, to prevent the accumulation therein of inflammable vapour, and all ventilating openings must be protected by strong wire gauze, mesh about 800 to the square inch, or 28 to the lineal inch. (See diagram, Fig. 93.)

If in sunk tanks as set out in the conditions, see p. 169.

Both sunk tanks and aboveground stores should be placed in positions in the open air at safe distances from buildings or inflammable materials.

In all cases where tanks are filled by pipes, the tanks require inlets by which a medium can be admitted to occupy the space of the oil or spirit withdrawn. The space may be charged with air, water, or carbonic acid gas.

Numerous patents have been taken out to secure the safety of the tanks by isolating the spirit from any chance flame or spark. Some of the systems force the spirit out by pressure upon the liquid, but the more general way is by drawing off with a pump.

Attached to many of the pumps are ingenious self-measuring arrangements that keep a check on the quantities delivered or withdrawn.

It must be remembered that petrol will not mix with water, but will adhere to and can be conveyed from place to place by drops of water.

The Local Authorities have power to grant licences for small quantities not exceeding 10 gallons (45 l.), to be kept in yards when a space measuring

at least 5 feet (1·5 m.) × 5 feet (1·5 m.) is provided, and which are exclusively appropriated to the purpose of such storage, and are not within any inhabited building.

The petroleum spirit in the tanks of motor cars standing in garages is included in the terms of the petroleum licence, and it is desirable that garages should be constructed of fire-resisting materials and be provided with impermeable floors. Garages should be well ventilated, and any artificial lighting and heating should be afforded by means that will not ignite inflammable vapour. A plentiful supply of sand and extinguishers charged with carbon-tetra-chloride or chemicals which produce a foam should also be kept in convenient positions. See p. 170.

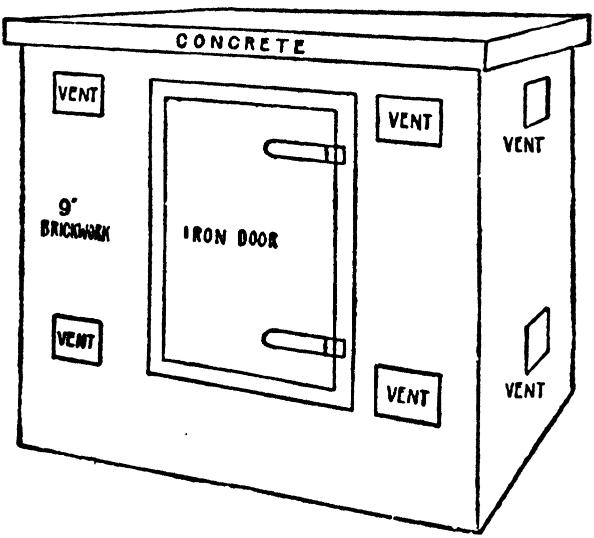


Fig. 93.

The small sizes of Foam Extinguishers are operated in a similar manner to the ordinary chemical fire extinguishers. In some depôts in which considerable quantities of petrol and light oils are stored, sufficiently large tanks are provided charged with the ingredients ready to cover considerable areas in case of fire with the foam.

One of the safest methods of heating garages is by means of hot water, steam, or warm air conducted by pipes or ducts from a stove placed outside the garage in a position where there is no risk of any inflammable vapour being ignited.

Only safe lights suitably protected should be used in inspection pits on account of the tendency of the heavy petroleum vapour to collect in such pits. No connections for portable electric lamps should be fitted in inspection pits.

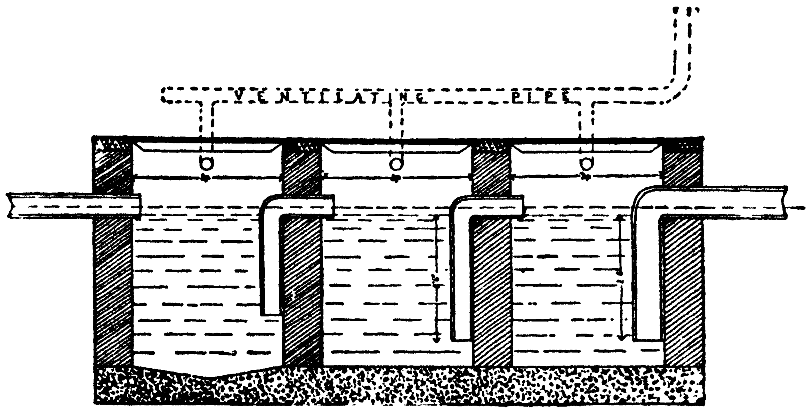
Inspection pits should not be provided with a drain unless such drain passes to an approved petroleum interceptor (see Fig. 94).

Before installing any system or adopting any method of heating garages,

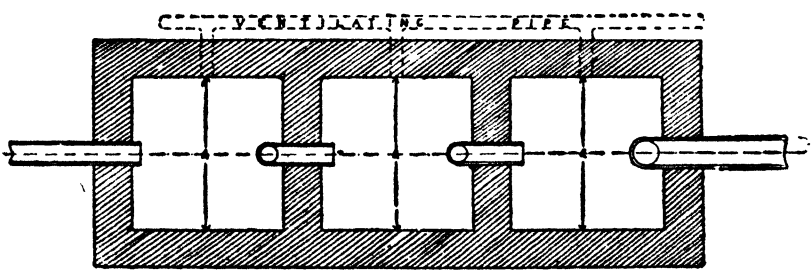
licensees and applicants for licences should communicate with the Executive Officer under the Petroleum Acts or the Chief Officer of Police in the district.

Any person licensed to keep petroleum spirit may, subject to the enactments as to Hawkers and Pedlars, and to the regulation of the Petroleum (Hawkers) Act, 1881, hawk petroleum by himself or his servants.

Petroleum spirit for use in motor cars or motor cycles may be kept without a licence if the restrictions laid down in the Regulations of the Secretary of State under the Locomotive on Highways Act are strictly observed, but if it is sold a licence is necessary.



Longitudinal Section.



Sectional Plan.

Fig. 94.

CONDITIONS USUALLY INSERTED IN LICENCES FOR PETROLEUM STORAGE IN SUNK TANKS FOR USE ON MOTOR VEHICLES.

(1) That the Petroleum be stored in strong securely-closed steel or iron tanks sunk underground in the open yard in the positions shown on the plans submitted.

(2) That the tanks be surrounded by fine concrete of approved thickness, the concrete over the tanks or that part of the tanks containing the manhole and pipe connections being raised to an approved height above the surrounding ground level, or that the tanks be contained in a substantial brick and cement chamber or concrete chamber just large enough to hold the tanks, with all spaces not occupied by the tanks filled in with dry sand or well-tempered clay, and that the tanks be covered with concrete of *approved thickness*, such concrete being raised as above indicated.

(3) That the petroleum be delivered into the storage tanks under seal, and that for the purpose of charging the tanks of vehicles the petroleum be—

(a) Pumped through strong iron piping by means of approved pumps into aboveground measuring tanks of a capacity not exceeding 30 gallons, fixed in approved positions, and run thence through sound hose, fitted with secure tap and nozzle, into the tanks of the vehicles, or

(b) Pumped through strong iron piping, by means of approved pumps, into an aboveground service tank of approved capacity, fixed in an approved position, be run thence through strong iron piping into measuring tanks of a capacity not exceeding 30 gallons, fixed in approved positions, and thence through sound hose, fitted with secure tap and nozzle, into the tanks of motor vehicles, or

(c) Pumped by means of approved measuring pumps, fixed in approved positions, through sound hose fitted with secure tap and nozzle, into the tanks of motor vehicles.

(4) That all service or measuring tanks be fitted with overflow and emptying pipes returning to the storage tanks.

(5) That all tanks, pumps, pipes, and fittings be strongly constructed of the best materials; that all pipes connected to the storage tanks, including the dipping hole pipe, but excluding the ventilating pipe, be carried down close to the bottom of the tanks; that all tanks be fitted with ventilating pipes, and that such pipes be carried up to an approved height in the open air, and that their upper ends be protected with fine wire gauze, mesh about 28 to the lineal inch.

(6) That all tanks, pumps, pipes, and fittings be maintained in good order, and free from leakage.

(7) That the surface drainage of the premises be passed into petroleum intercepting chambers, constructed in accordance with the design approved by the local authority (see Fig. 94).

(8) That if petroleum is kept in the tanks of vehicles standing in the garages the means adopted for artificially lighting and heating the garages shall be such as will not ignite inflammable material.

(9) That all necessary precautions be adopted, to the satisfaction of the local authority, for preventing the outflow of petroleum from any portion of the premises.

(10) That, if it is necessary to draw off the spirit from the tank of a motor vehicle, or the hose of the installation, the spirit be drawn off only into a strong metal vessel labelled "Highly inflammable, petroleum," such vessel to be at once securely closed with a screw cap, and emptied as soon as possible either into the storage tank or the tank of another motor vehicle; that a pail be not used for the purpose; and that the spirit be handled only in the open air or other approved position, and not within 20 feet of any fire or flame.

(11) That explosives, matches, or other inflammable or explosive substances be not in or near any place where petroleum is kept or used for charging vehicles.

(12) That fire, flame, or such artificial light as will ignite inflammable vapour be not within 20 feet of the storage place or within 20 feet of a vehicle containing petroleum in its tank, or within 20 feet of the place where the tank of a vehicle is charged with or emptied of petroleum.

(13) That, subject to the approval of the local authority inspector, not exceeding a quarter of a pint of petroleum spirit and one pound of indiarubber solution be kept in approved metal vessels for use in tyre repairing.

(14) That due precautions be at all times taken for the prevention of accident from fire, and that every precaution be taken for preventing the leakage of petroleum or the escape of inflammable vapour.

(15) That buildings or places in which petroleum is kept or used be at all times thoroughly ventilated into the external atmosphere, and that sufficient sand to extinguish fire be kept in or near such buildings or places.

(16) That the licensee do take effectual precautions for preventing unauthorised persons and all persons under the age of 15 years from obtaining access to the place of storage or to any petroleum upon the premises.

(17) That petroleum be not allowed to enter any inlet or drain communicating with a public sewer.

(18) That the arrangements for the storage or use of petroleum as approved by the

local authority, and as seen by the local authority's inspector last before the granting of the licence, be in all respects kept and maintained, unless the consent of the local authority is given in writing to any departure therefrom.

(19) That every authorised officer of the local authority be at all times allowed free access to the premises of the licensee for the purpose of ascertaining if the above conditions are properly observed; and that the licensee do, by himself or his representative, give any assistance for that purpose which such officer may require, and do furnish samples of substances alleged to be petroleum.

(20) That petroleum be not kept or used otherwise than as specified in the licence.

(21) That any further necessary works be carried out to the satisfaction of the officer of the local authority.

THE DANGERS OF PETROLEUM SPIRIT.

(COPY OF WARNING ISSUED BY THE LONDON COUNTY COUNCIL).

This warning is issued by the Council as it appears from the number of petroleum spirit fires and the circumstances of their origin, that many people do not realise the serious risks incurred through the careless handling of petroleum spirit.

The term Petroleum Spirit is applied to a number of liquids known as benzine, benzoline, benzole, carburine, gasoline, motor spirit, naphtha, pentane, petrol, etc.

Such liquids may only be kept under licence or in accordance with regulations.

The dangerous character of these liquids is due to the fact that at ordinary temperatures they freely give off a heavy inflammable vapour which, when mixed with air in certain proportions, is also explosive. Given favourable conditions the vapour, owing to its density, will flow a considerable distance. An explosion, has been known to take place through vapour travelling over 40 feet to the flame of a lamp. Recently in London, while petrol was being drawn from a car in the road, a small quantity was spilled on the ground and the vapour became ignited by a portable furnace 30 feet away. The car was destroyed and adjoining premises were injured.

It is very difficult to put out a petroleum fire. Water may make the outbreak more dangerous by scattering the flaming spirit. Petroleum burns easily on water and a serious feature of some riverside petroleum fires has been the presence of patches of flaming spirit flowing on the river with the current. Sand or earth is an effective agent for dealing with a small fire. Many chemical extinguishers are good, but they sometimes fail to act, and a supply of sand should always be available where petroleum is stored or used.

Storage.

A store should be properly constructed and fire-resisting. The two undermentioned cases show the need for proper storage.

> A quantity of petrol in two-gallon cans was stored illegally under a tarpaulin in an open yard. A light was thrown down and the vapour from a leaky can became ignited and the whole quantity was involved.
>
> A fire occurred on a car in a garage. The door of the petrol store did not fit properly and vapour from a leaky can or cans escaping from the store, was ignited by the fire, and flashed back through the crack and a serious fire resulted.

Motor Car Fires.

Many fires are caused by drivers of motor cars attempting to fill the tanks of their vehicles in the presence of lighted oil or acetylene lamps. Some have been caused by a driver striking a match to see how much petrol he had in the car tank. The foolishness of such practices cannot be too strongly emphasised.

Smoking.

Smoking in garages or anywhere near a petrol store should be prohibited. A lighted match thrown down carelessly may cause damage amounting to thousands of pounds. There is reason to fear that many garage fires of mysterious origin have been due to this cause.

Smokers in taxi-cabs should also be careful where they drop their glowing cigarette or cigar ends. Many taxi-cab fires are believed to have been caused by a lighted cigarette end being dropped in the mat and left there smouldering; the mat ultimately bursting into flame after the cab had been placed in the garage and involving the petrol tank.

Electrical Fittings.

Care should be exercised with the electrical fittings both on a car and in the garage. Damaged or knotted flexible wiring may cause an accident, and the insulation should be carefully examined from time to time to see that it is not frayed.

No electrical connections should be fitted in inspection pits.

Cans of Petrol.

The common two-gallon can of petrol, by reason of its portability, is often taken into places where it is likely to cause an accident. It should never be taken inside a dwelling. Some time ago a two-gallon can of petrol was taken inside a house in North London by a motor cyclist. It would appear that the screw-cap was removed in the hall and that in some way the spirit became ignited. The can was upset and the burning spirit flowed over the floor. A fierce fire ensued and in about 15 minutes five of the six persons in the house were fatally injured.

Emptying Petrol Tanks of Motor Cars.

Petroleum spirit should only be drawn off from a car tank into a vessel intended to hold petrol. At a North London garage a car was under repair and the spirit was drawn off into a pail which was then placed aside. Later on, another man entered the garage, and thinking the pail contained water, he, by way of a practical joke, threw the contents over his comrades. A lighted forge in the vicinity ignited the vapour and three of the men died as the result of their injuries.

Domestic Dry Cleaning.

It is a dangerous practice to use petroleum spirit for cleaning articles in the home. A fatal accident occurred recently through a woman attempting to clean the upholstery of a chair with a small quantity of petroleum spirit. There was a fire in the room and the vapour given off was evidently ignited by the fire.

A distressing fatality happened some few years ago through a child attempting, in the absence of her parents, to clean her doll's clothes with petroleum spirit. There was a gas jet in the room, the petroleum vapour ignited, and the child was burned to death.

Petroleum Hairwash.

Serious accidents have occurred through the use of petroleum spirit either alone or in mixture with other liquids, for cleansing the hair. So dangerous is this practice that the Council issued a special warning on the subject to London hairdressers. Even if there is no fire or flame near, there is risk of the ignition of the petroleum vapour by a spark from electricity generated by the rubbing of the hair (see p. 155).

Blow Lamps.

The careless or ignorant use of petroleum spirit blow lamps is a frequent cause of accident often involving serious injury to the operator. The undermentioned are not isolated cases: —

> An employee was pumping up a blow lamp filled with petroleum spirit. The petrol in some way became ignited, the lamp burst, and flaming spirit was blown in his face, subsequently causing his death. On investigation it was found that the lamp was only intended for the use of paraffin.
>
> A blow lamp containing petroleum spirit exploded through being heated on a gas jet. One man was killed and two seriously injured.

Drains.

A serious danger arises from allowing petroleum spirit to gain access to the drains, and a number of accidents have occurred in the London sewers from this cause. Two men were badly injured in a London sewer recently by an explosion of petrol vapour and in this case the burning liquid flowed on the surface of the sewage for a considerable distance.

Explosions.

The explosive force of a mixture of air and petroleum vapour is shown by the following accidents:—

> Eleven men were engaged recently at a wharf in removing a petroleum spirit tank from a barge. The tank was thought to be empty, but evidently contained vapour. An oxy-acetylene blow-pipe was used in connection with the work and the flame caused the mixture of vapour and air in the tank to explode with such force as to shatter the tank. Seven of the men were killed and the remainder injured.
>
> A few years ago, while hides were being degreased by petroleum spirit in a large iron tank an explosion occurred which shattered the tank and hurled portions of the heavy iron cover through an adjoining 9-inch brick wall and practically wrecked the building in which the tank was situated.

Repairing Petrol Tanks.

Fatal accidents have occurred during the repair of tanks or other metal vessels which have contained petroleum. Vapour remains in such vessels and unless it is removed, the application of the heat necessary to solder or braze a joint will probably result in an explosion. Quite recently an explosion occurred in this way and a piece of flying metal caused fatal injuries. Steps should therefore be taken before any repair is executed to ensure that the vessel is completely free from vapour.

A convenient way of doing this is to fill the vessel with water after draining out all spirit. If possible, the vessel should be immersed in water and agitated beneath the surface so as to get rid of any pockets of vapour or spirit which the mere filling with water might not displace.

To leave the vessel in the open air for a few days with its openings uncapped is not sufficient to get rid of the vapour. Nor is a simple washing. Repeated washings are necessary, preferably with warm water.

Petroleum Mixtures.

This is a term applied to substances containing petroleum spirit such as indiarubber solution, quick drying paints and varnishes. Such substances need to be treated with the same care as petroleum spirit as they give off inflammable vapour at ordinary temperatures.

SUGGESTED NOTICE FOR EXHIBITION IN GARAGES.

PETROLEUM ACTS, 1871-1881.

Notice to Motor Car Owners, Chauffeurs, Etc.

The following rules are in force in this Garage, and any infringement thereof will be punished.

Smoking is strictly prohibited.

Petrol must not be used for any purpose other than charging the tanks of cars.

Petrol or dirty spirit must not be put down the drains.

The tank of a car must not be charged or emptied near a light or fire, or while the car lamps are alight.

Not more than one vessel containing petrol may be opened on these premises at one time. Such vessel must be opened and the tank of the car charged or emptied only in the open air.

Extract from the Regulations of the Secretary of State—

Every person managing or employed on or in connection with any light locomotive shall abstain from every act whatever which tends to cause fire or explosion, and which is not reasonably necessary, and shall prevent any other person from committing such act.

Any person infringing these Regulations is liable to a penalty of £10.

Avis aux Propriétaires, Mécaniciens, Chauffeurs, etc., D'automobiles.

Le règlement ci-dessous est applicable à ce Garage; toute contravention sera poursuivie selon la loi.

Il est défendu de fumer.
Le pétrole en dépôt sur les lieux ne doit servir qu'à remplir les réservoirs des automobiles.
Le pétrole ou tout résidu d'hiule minérale ou autre produit ne doit pas être jeté dans les égouts.
Il est défendu d'emplir ou de vider le réservoir d'une automobile près d'une lumière ou d'un feu, ou quand les lampes de l'automobile sont allumées.
On ne peut ouvrir qu'un seul bidon contenant du pétrole à la fois dans cet établissement. Il faut que le dit bidon soit ouvert et que le réservoir de l'automobile soit rempli ou vidé en plein air seulement.

Extrait des lois et règlements promulgués par le Secrétaire d'Etat—

Toute personne qui dirige ou a charge, à un titre quelconque, d'une automobile, doit s'abstenir de tout acte qui peut causer un incendie ou une explosion et qui n'est pas absolument nécessaire et empêcher toute autre personne de commettre un tel acte.

Quiconque commet une infraction à ces lois et règlements est passible d'une amende de dix livres sterling.

Verordnung zur Kenntnissnahme der Motorfuhrer (Chauffeurs) und anderer, die es betrifft.

Die folgenden Vorschriften gelten in diesem Motor-Lagerplatz (Garage)—und jede Uebertretung derselben wird streng bestraft werden.

Das Rauchen ist streng verboten.
Das Petroleum darf zu keinem andern Zweck verwendet werden ausser zur Füllung der Petrol-Behälter der Motorwagen.
Petroleum oder verunreinigter Spiritus darf nicht in die Wasserableitungs-Röhren gegossen werden.
Der Petrol-Behälter eines Motorwagens darf nicht gefüllt oder entleert werden in der Nähe von licht oder Feuer, oder während des Brennens der Wagenlampen.
Nicht mehr als ein Petrol-Gefäss darf in diesem Geschäfts-Lokal zu derselben Zeit geöffnet werden. Ein solches Gefäss darf geöffnet und der Petrol-Behälter gefüllt oder geleert werden—nur in der freien Luft.

Auszug aus den Verordnungen des Staatssecretärs—

Jedermann, der mit der Führung einer leichten Locomotive betraut oder in irgend einer Eigenschaft darauf beschäftigt ist, muss sich von jeder Handlung enthalten, welche einen Brand oder eine Explosion verursachen könnte—und die vielleicht nicht einmal notwendig wäre. Derselbe soll auch andere Personen daran hindern eine solche Handlung zu begehen.

Jedermann, der diesen Verordnungen zuwider handelt ist einer Strafe von £10 Sterling unterworfen.

Heavy Oils.

The increasing labour troubles in our coalfields and the delays that occur in the transport of goods over the railways, makes it necessary for users of coal to provide space for a considerable supply of fuel to be stored. The result is that oil fuel for boilers is fast displacing coal, particularly in ships.

The heavy oils most commonly used for this purpose are the residual from the refineries, after the light oils and volatile elements have been abstracted.

The oil is delivered under pressure by pumps to the burners, where it is atomised, admixed with a regulated and in some cases preheated air supply and consumed as a smokeless flame. The result, great flexibility of steam production, clean and relatively comfortable stokeholds, and a very considerable reduction of the exacting and heavy labour of stoking with solid fuel under sea-going conditions.

The flash point of these heavy oils is about 160° F. (71° C.), and they occupy only about one-third the space required for coal of the same calorific value. By means of pipes from the tanks to the furnaces the stoking and consequent dirt is considerably reduced. In cases where the tanks are level with, or below the fires, it is usual to apply pressure to force the oil through the pipes, and with some of the heavier kinds and in cold climates the oil requires to be heated before it will run. Some of the crude oils direct from the wells have been used, but it is found that they contain sufficient volatile spirit to give off explosive vapour when heated. The crude oil also contains grit and other foreign matter which, if not carefully strained off, will obstruct the flow of the oil to the burners.

It is economical to strain heavy oil thoroughly as it is received from the wells or works, for the immediate removal of the sand and other foreign matter much reduces the trouble in handling the oil when passing through the supply lines. On shore, the pipes for supplying the furnaces from the tanks should be laid underground in soil below the frost line and it is well for them to have a fall towards the tank for drainage. Only moderate heat should be employed, just sufficient to make the oil flow, otherwise a vapour may be generated that would be dangerous. The heating should, of course, be obtained by means of steam and should not cause the oil to be heated within 50° F. (10° C.) of its flash point.

The most approved way of transferring the oil from the tanks to the burners is by pumping at a pressure of about 30 lbs. on the square inch (2 atms.). It is necessary, if a steady pressure is required at the burner—and some engineers maintain that an even fire can only be obtained by steady supply—to provide receivers or air chambers on the lines of pipes to absorb the pulsation of the pumps.

In order to obtain a steady flow, storage tanks are sometimes placed near the furnaces, and the oil is kept under 100 lbs. (6·8 atms.) pressure by air from compressors in the works. An installation of this kind cannot be recommended, as in case of a fractured pipe or burner and a fire resulting, the difficulty of cutting off the supply would be considerable.

Tanks fixed upon roofs or above furnaces should not be allowed, as they have been the cause of many fires.

From the above it will be understood that the important problem is to provide shut-off valves and other necessary fittings upon the pipe lines, ready for *instant use* in case of fracture of any of the pipes under pressure.

All valves should be plainly marked and so situated that they can be readily reached and closed.

Automatic shut-off valves are obtainable that with proper care will instantly close when there is an increase in the flow of the oil.

If it is not possible to exercise immediate and absolute control, buildings

in which oil fuel installations are fitted are subject to considerable danger from fire.

Oil fuel installations in steamships, and particularly passenger ships, are subject to the regulations laid down by the Board of Trade Marine Department. The regulations alter from time to time, and owners and builders should keep in touch with the Board of Trade Surveyors, and thus be able to carry out strictly the recommendations.

During the past few years large stores of petroleum have been accumulated in depôts, chiefly situated at a distance from towns, and generally upon the banks of, or within easy reach of, navigable rivers. The dangers attending the storing of large quantities of inflammable liquids were not at first appreciated, with the result that large losses by fires were suffered before proper measures were taken to isolate the tanks and to prepare the sites for accidents that were bound to occur.

The area of the modern store to contain large supplies must be sufficient to provide a space round each tank large enough to hold the whole contents of the tank without unduly endangering those adjacent to it.

The areas are usually enclosed and divided from each other by low brick walls, against which is banked earth to form a dam of ample strength to contain the contents of a tank. Grass, timber, or any combustible matter must not be allowed within these enclosures.

The conditions attached to licences issued by the London County Council for the conveyance of petroleum and the regulations as to the execution and maintenance of petroleum oil depôts cover the whole subject; they are, therefore, given *in extenso*.

PETROLEUM ACTS, 1871 TO 1879.

Conditions governing the Conveyance by Road of Petroleum to which the Petroleum Acts apply.

These Conditions are recommended by the Home Office, but they do not operate unless incorporated in a licence issued by the local authority under the Petroleum Acts.

1. Every vehicle carrying petroleum and every vessel containing the same shall be strongly constructed and shall be maintained in good condition. The vehicle shall be fitted with adequate sides and the load shall be protected from sparks, lighted matches, etc., by a cover of fire-resisting material. The vessels shall be of metal, and shall be securely closed. They shall not be packed so as to project beyond the sides or back of the vehicle.

2. No fire or artificial light capable of igniting inflammable vapour shall be carried, nor shall smoking be allowed, on the vehicle.

3. A supply of sand or other efficient means of extinguishing an outbreak of fire shall be carried in an accessible position on the vehicle.

4. The engine and fuel tank of a mechanically driven vehicle shall be effectively screened from the body of the vehicle by a fire-resisting shield carried up above the height of the load and down to within 12 inches of the ground, and the exhaust shall be wholly in front of this shield. A quick-action cut-off valve shall be fitted to the fuel feed pipe in an easily accessible position.

Provided that this shall not be deemed to prohibit the employment during an emergency of a vehicle not so constructed and fitted for a period not exceeding seven days.

Provided also that the requirement as to the provision of a fire-resisting shield shall not apply to a vehicle constructed prior to the 1st January, 1925, for a period of five years from that date.

5. Tank-wagons shall be constructed to a specification approved by the licensing authority and shall, together with their connections and fittings, be maintained in good condition.

6. When a tank-wagon is being filled or emptied the horses shall be removed and the wheels securely scotched or, if mechanically driven, the engine shall not be run until all tanks are securely closed.

7. Petroleum in cans or other packages shall not be carried on tank-wagons containing petroleum spirit except in the case of composite vehicles approved by the licensing authority, in which the tank equipment satisfies the conditions applying to tank-wagons.

8. All due precautions shall be taken to prevent accident by fire or explosion.

9. These recommendations shall not apply to any vehicle other than a tank-wagon containing petroleum spirit provided that the quantity of petroleum spirit carried as load on the vehicle does not exceed 30 gallons in tins each containing not more than 2 gallons or in drums each containing not more than 10 gallons, or 50 gallons in a single steel barrel.

PETROLEUM ACTS, 1871 TO 1879.

SPECIFICATION FOR TANK-WAGONS RECOMMENDED BY THE HOME OFFICE.

1. The vehicle, including the tank and fittings, shall be strongly constructed of fire-resisting materials and shall be maintained in thoroughly good condition. There shall be a clear space of not less than six inches between the tank and the fire-resisting screen.

2. The quantity of petroleum carried as load in any tank-wagon shall not exceed 2,500 gallons. (In the County of London only 2,000 gallons are allowed.)

Provided that if the capacity of the tank exceeds 1,500 gallons the weight of the engine and load shall be distributed over the three axles of a six-wheeled combination vehicle (tractor and trailer), and when the vehicle is engaged in the conveyance and delivery of petroleum spirit it shall be constantly attended by not less than two competent persons.

3. The tank shall be divided into self-contained compartments, any one of which shall not contain more than 600 gallons.

4. The draw-off pipes shall be fitted with internal valves in addition to strong and secure taps and screw caps, and the taps shall be enclosed in a strong locked box of hard wood or other suitable material, and those at the rear shall be protected by the rear cross-member of the frame.

5. The filling-pipes shall be carried down nearly to the bottom of the tank and shall each terminate in such a way as to provide at all times a liquid seal at the bottom of the pipe; or the covers over the filling openings shall be kept locked except during the operation of filling, and the keys shall be retained by a responsible person.

6. The dipping pipes shall be carried down to the bottom of the tank, and any openings in them other than the upper orifice shall be covered with fine wire gauze of not less than 28 meshes to the linear inch.

7. The ventilating openings shall be covered with fine wire gauze of not less than 28 meshes to the linear inch, protected by covers when not in use.

N.B.—Recommendations Nos. 3, 5, and 6 shall not be deemed to apply to tank-wagons constructed prior to January 1st, 1925, for a period of five years from that date.

REGULATIONS MADE BY THE LONDON COUNTY COUNCIL in pursuance of Section 6 of the London County Council (General Powers) Act, 1912, as to the execution and maintenance of works for diminishing or preventing the risk of the outflow of petroleum oil flashing between 73° F. (22·7° C.) and 150° F. (65·5° C.), inclusive, from petroleum oil depôts in the Administrative County of London (exclusive of the City of London).

Enclosure.

(1) A storing place for petroleum oil (other than a storing place within a building or a storing place sunk below the ground level so as to form a pit) shall be surrounded with an embankment (hereinafter called a retaining embankment) or a wall of brick, tone or Portland cement concrete, either plain or reinforced (hereinafter called a retaining wall), so designed and constructed as to form an enclosure capable of containing and retaining the quantity of petroleum oil required to be retained in accordance

with regulation 10. Provided that the top of such retaining embankment or retaining wall shall be at least 3 inches higher than is necessary to contain and retain the quantity of petroleum oil aforesaid.

Retaining Embankment.

(2) A retaining embankment shall be at least 2 feet thick at the top with slopes on each side of 1½ to 1. It shall be constructed with a central concrete core not less than 12 inches thick at the top with a batter on each side of 1 in 24 to the level of the enclosure formed in pursuance of regulation 1. The core shall be taken down of the same thickness as at this level to such a depth depending upon the nature of the soil as will effectually prevent any leakage of petroleum oil. The earthwork round the core shall be composed of materials well watered and consolidated.

Retaining Walls.

(3) A retaining wall if of brick or stone shall be constructed with Portland cement mortar and the thickness at the top of a brick, stone or plain Portland cement concrete wall shall be not less than 18 inches.

(4) A retaining wall of reinforced concrete shall be not less than 6 inches thick at the top and the tensile portion of the stresses shall be wholly taken up by steel reinforcements placed not nearer the surface than 2 inches; the stresses on both the steel and concrete shall not exceed those permitted under the regulations of the London County Council made under the provisions of Section 23 of the London County Council (General Powers) Act, 1909.

(5) A retaining wall shall be taken down to such a depth and provided with such foundations, depending upon the nature of the soil, as will ensure stability in all respects and effectually prevent any leakage of petroleum oil.

Design and Materials.

(6) The design and construction of any works required by these regulations in forming a storing place for petroleum oil and the quality and proportion of all concrete and other materials used for the purposes of any works required by these regulations shall be subject to the approval and satisfaction of the London County Council.

Storage in Pit.

(7) The level of a site of a storing place for petroleum oil may be sunk so as to form a pit below the ground level, provided that a wall be constructed around such pit of sufficient strength to resist the external earth pressure. Provided also that the top of such wall shall be at least 3 inches higher than is necessary to contain and retain the quantity of petroleum oil required to be retained in accordance with regulation 10. Provided also that if an embankment or wall is erected around such storing place above the ground level such embankment or wall shall be a retaining embankment or a retaining wall constructed in accordance with the requirements of these regulations.

Openings and Pipes.

(8) No opening in a retaining embankment or retaining wall shall be made except as provided in regulation 9, and all pipes shall be carried over the top of such embankment or wall.

Storage in Building.

(9) A storing place for petroleum oil may be within a building on the ground or basement floor only provided that the London County Council may in any particular case give its consent in writing to the use of a floor above the ground floor as a storing place for a portion of the total quantity of petroleum oil kept within the building.

Provided also that where a storing place for petroleum oil is in the basement of a building the walls forming the storing place shall be of sufficient strength to resist the external pressure, and shall be designed and constructed so as to conform to the require-

ments of regulation 1 relating to retaining walls and shall be impervious and incombustible to the height necessary to meet the requirements of regulation 10.

Provided also that where a storing place for petroleum oil is on the ground floor of a building the walls forming such storing place shall be designed and constructed so as to conform to the requirements of these regulations relating to retaining walls, or if not so designed and constructed shall be impervious and incombustible to the height necessary to meet the requirements of regulation 10, and provision shall be made to the satisfaction o. the London County Council for the immediate outflow and the emptying by gravitation of the contents of such storing place into a basement which shall be constructed as a storing place for petroleum oil in accordance with this regulation and be of a capacity to contain and retain the whole of the petroleum oil stored in such building.

Provided also that where a storing place for petroleum oil is on any floor of a building above the ground floor the floor and the walls of such storing place to the height necessary to meet the requirements of regulation 10 shall be impervious and incombustible, and provision shall be made to the satisfaction of the London County Council for the immediate outflow and the emptying by gravitation of the contents of such storing place into the ground floor or basement which shall be constructed as a storing place for petroleum oil in accordance with this regulation, and be of a capacity to contain and retain the whole of the petroleum oil stored in such building.

No opening shall be made in the floor or in the walls within the height necessary to meet the requirements of regulation 10 and within 3 inches above such height of a storing place within a building except as directed in writing by the London County Council.

Retaining Capacity of Enclosure.

(10) Every storing place for petroleum oil shall be capable of retaining the following quantity of such oil, namely :—

With respect to tanks, barrels or other receptacles, each of a capacity not exceeding 250 gallons within such storing place—75 per cent. of their total capacity; and in addition :—

Where there is not more than one tank, barrel or other receptacle of a capacity exceeding 250 gallons within such storing place—90 per cent. of their total capacity;

Where there are not more than two tanks, barrels or other receptacles, each of a capacity exceeding 250 gallons within such storing place—80 per cent. of their total capacity

Where there are three or more tanks, barrels or other receptacles, each of a capacity exceeding 250 gallons within such storing place—75 per cent. of their total capacity;

and no structure shall be erected in a storing place without the consent of the London County Council in writing.

Pipes.

(11) Every pipe connected to any tank, barrel or other receptacle of a capacity exceeding 250 gallons inside a storing place for petroleum oil, and passing beyond the retaining embankments or retaining walls or the walls of a storing place within a building shall be so fitted and constructed as not to be capable in any circumstances accidental or otherwise of syphoning out any petroleum oil in such tank, barrel or other receptacle, and every pipe communicating with such tank, barrel or other receptacle, and extending beyond the storing place, shall, if connected to a tank, barrel or other receptacle at any point below the level of the surface of any petroleum oil in such tank, barrel or other receptacle be fitted with a suitable screw-down valve at a point approved by the London County Council inside the storing place, and in addition a suitable valve on the mouth of the pipe inside such tank, barrel or other receptacle, both valves to be each capable of effectually preventing the outflow of petroleum oil from such tank, barrel or other receptacle, and both valves shall be kept securely closed except when it is required to pass petroleum oil through the pipe. A secure tap shall also be fitted to the end of such pipe outside the storing place.

Sump and Pump.

(12) Any storing place for petroleum oil liable to receive rain-water or flood-water shall be provided with a sump at the lowest point within such storing place and a pump to be approved by the London County Council permanently fitted in connection therewith together with the necessary pipes and fittings so that water may be pumped out.

Drain not to be in Storing Place.

(13) No drain outlet or connection to any sewer shall be within any storing place for petroleum oil.

Maintenance and Repair.

(14) Nothing shall be done to or in any storing place for petroleum oil which will diminish or tend to diminish the retaining capacity of such storing place below that required by regulation 10, and such retaining capacity and all embankment walls, pumps, pipes and works required by these regulations shall be properly maintained at all times.

Specific Gravity of Petroleum Oil.

(15) For the purpose of calculating the strength and stability of the embankments and walls required by these regulations the specific gravity of petroleum oil shall be deemed to be that of water.

ABSTRACT OF THE REGULATIONS AS TO THE KEEPING, SALE, AND CONVEYANCE OF CARBIDE OF CALCIUM IN THE COUNTY OF LONDON.

This Abstract has no legal validity, and is intended only for the information and guidance of the persons concerned. For further information reference should be made to the Petroleum Acts, 1871-1881, *and to the Order in Council made thereunder, dated* 14*th July,* 1922.

General.

1. By an Order in Council, dated 14th July, 1922, Carbide of Calcium can only be kept in pursuance of a licence granted by the local authority (in London, the London County Council), except as follows :—

Exemption.

Not exceeding 28 lbs. of Carbide may be kept without licence, provided the following conditions are observed :—

(*a*) The Carbide shall be kept only in a metal vessel or vessels hermetically closed at all times when the Carbide is not actually being placed in or withdrawn from such vessel or vessels.

(*b*) The vessels containing the Carbide shall be kept in a dry and well-ventilated place.

(*c*) Due precautions shall be taken to prevent unauthorised persons from having access to the Carbide.

(*d*) Notice shall be given of such keeping to the Council, and free access shall be afforded to their duly authorised inspector to inspect the portion of the premises where the Carbide is kept and the generator is situated.

Where a fixed generator is used on the premises :—

(*e*) Full and detailed instructions to be supplied by the makers as to the care and use of the generator shall be kept constantly posted up in such place as to be conveniently referred to by the generator attendant.

Condition (*e*) does not apply to lamps for vehicles or other portable lamps.

Where it is desired to keep more than 28 lbs., or where the above conditions cannot be complied with, application must be made to the Council for a licence.

Where the quantity kept is limited to 5 lbs. in separate hermetically closed metal vessels, each containing not more than 1 lb., notification to the Council is not necessary.

Labelling Vessels.

2. Where Carbide of Calcium is—

(a) Kept at any place; or

(b) Sold or exposed for sale,

the vessel containing it shall bear a label stating in conspicuous characters, the words, "Carbide of Calcium," "Dangerous if not kept dry," and with the following caution:—"The contents of this package are liable if brought into contact with moisture to give off a highly inflammable gas," and also stating the name and address of the owner or vendor.

Licences—Applications.

3. Application to the Council for a Licence to keep Carbide of Calcium at any place in the County of London (except the City of London) must be made upon the form provided for the purpose, which can be obtained by application in writing, addressed to the Chief Officer, Public Control Department, London County Council, County Hall, S.E. 1.

Fees.

4. Every application must be accompanied by a fee of 5s. in money, or, if sent through the post, by cheque or postal order for that amount payable to the order of the London County Council. The fee will be returned if the licence is refused or on receipt of a notification in writing that the application will not be proceeded with.

Particulars in Application.

5. Every application must state—

(a) The quantity of Carbide of Calcium which the applicant desires to keep;
(b) The proposed place and method of storage;
(c) If the Carbide is to be kept only for sale, or if it is to be used for the generation of Acetylene.

Plans.

6. Where the application is for a licence to store 10 cwt. or more, there must also be sent a plan, drawn to the scale of one-eighth of an inch to a foot, showing the places where it is proposed to keep or use Carbide and also the buildings, etc., within 50 feet of such places.

Mode of Storage.

7. Carbide of Calcium should be kept in strong metal vessels, and—

(a) Such vessels should be so constructed and closed as to prevent the admission of water and atmospheric moisture.
(b) Such vessels should be opened only for the time necessary for the removal of any required quantity of Carbide, or for the re-filling of the vessels.
(c) No one vessel should have a greater capacity than is necessary for containing 224 lbs. of Carbide.
(d) Every vessel containing Carbide of Calcium which is opened on the premises should be locked, or be in a locked receptacle, so as to prevent unauthorised persons gaining access to the contents.
(e) Copper should not be used in the construction of vessels for containing Carbide of Calcium.

Place of Storage.

8. Vessels containing Carbide of Calcium should be kept in dry and well-ventilated outbuildings with raised cement floors.

Small Quantities.

9. Small quantities of Carbide will, however, be allowed in shops, dwellings or workshops, upon licensed premises, if the arrangements are satisfactory.

Purity of the Carbide.

10. The Council grants licences to keep only such Carbide of Calcium as is pure (in a commercial sense), i.e., which contains no impurities liable to generate phosphoretted or siliciuretted hydrogen so as to render the gas evolved liable to ignite spontaneously.

Acetylene.

11. Where Carbide of Calcium is kept for the generation of Acetylene, such of the following precautions for ensuring safety as are applicable to the circumstances should be adopted—

Place of Manufacture.

(*a*) Every apparatus for generating and storing Acetylene should be placed in an outbuilding, or in a suitable place in the open air.
(*b*) Such building should be separated as far as may be practicable from inhabitated buildings, and should be well ventilated.
(*c*) No fire, flame or any artificial light or article capable of igniting acetylene should be taken into or near the building or place where a gas-making apparatus is situated.
(*d*) Where oxy-acetylene welding is carried on, an efficient oxygen trap should be provided on the acetylene supply pipe to blow pipe. This trap should be placed in such a position or be so enclosed, that in the event of an explosion in same there would be no risk of injury to the employees.

Generators.

12. Every Apparatus for generating acetylene, before being used on licensed premises, must be approved by the Council.

13. The conditions which such apparatus should fulfil before it can be considered as being safe are as follows.—

(*a*) The temperature in any part of the apparatus, when run for a prolonged period at the maximum rate for which it is designed, should not exceed 130° C. This may be ascertained by placing short lengths of wire, drawn from fusible metal, in those parts of the apparatus in which heat is liable to be generated.
(*b*) The apparatus should have an efficiency of at least 90 per cent., which, with Carbide, yielding 5 cubic feet per pound would imply a yield of 4·5 cubic feet for each pound of Carbide used.
(*c*) The size of the pipes carrying the gas should be proportioned to the maximum rate of generation, so that undue back pressure from throttling may not occur.
(*d*) The Carbide should be completely decomposed in the apparatus, so that any lime sludge discharged therefrom shall not be capable of generating more gas.
(*e*) The pressure in any part of the apparatus, on the generator side of the holder, should not exceed that of 20 inches of water, and on the service side of the same, or where no gas holder is provided, should not exceed that of 5 inches of water.
(*f*) The apparatus should give no tarry or other heavy condensation products from the decomposition of the Carbide.
(*g*) In the use of such apparatus, regard should be had to the danger of stoppage of passage of the gas and resulting increase of pressure which may arise from the freezing of the water. Where freezing may be anticipated, steps should be taken to prevent it.
(*h*) The apparatus should be so constructed that lime sludge cannot gain access to any pipes intended for the passage of gas or the circulation of water.
(*i*) The use of glass in water gauges, sight boxes, etc., should be avoided, but where glass is absolutely necessary as part of the apparatus it should be effectively protected against fracture.
(*j*) Each apparatus should be provided with a suitable cock fixed at a point immediately in communication with the interior of the generating chamber; and such cock should be fitted with a "nipple" or "nose piece" for india-rubber tube.

(*k*) The air space in a generator should be as small as is consistent with the proper working of the apparatus.
(*l*) The use of copper should be avoided in such parts of the apparatus as are liable to come into contact with the Acetylene.
(*m*) The various parts of the apparatus should be of adequate strength.
(*n*) Escape of gas from the apparatus should be carefully guarded against: as a general rule generators should be fitted with blowoff pipes carried up to a suitable point in the open air.
(*o*) An open tank should be provided near the apparatus, but in the open air, for the reception of all residue from the Carbide; and such residue should remain for at least ten hours in ten times its bulk of water in such tank.
(*p*) Precautions should be adopted for preventing any lime sludge being discharged into the drains.
(*q*) No person should have charge of an apparatus until he has been properly instructed in its management;

but some of these conditions may be varied by the Council where equal or greater safety is ensured by the adoption of other precautions.

Duration of Licence.

14. Licences are granted for keeping Carbide of Calcium for periods not exceeding one year, and prior to expiration, application must be made for their renewal. Notice of the expiration, and a form of application for renewal, are sent to each Licensee at the proper time.

Conveyance of Carbide of Calcium.

15. Where Carbide of Calcium is sent or conveyed, the vessel containing it shall bear a label stating in conspicuous characters, the words, "Carbide of Calcium," "Dangerous if not kept dry," and with the following caution :—"The contents of this package are liable if brought into contact with moisture to give off a highly inflammable gas," and also the name and address of the sender.

16. Carbide of Calcium conveyed to or from licensed premises must be conveyed in strong, hermetically sealed, metal vessels.

Inspection.

17. Every authorised officer of the Council must at all times be allowed free access to the licensed premises for the purpose of ascertaining if the conditions of the licence are properly observed, and of obtaining samples of Carbide of Calcium on payment therefor. The licensees must give any assistance which such Officer may require.

Note.—The Master of **a ship entering the River Thames** with Carbide of Calcium must immediately give notice to the Authorities. The ships must be efficiently ventilated, and no Carbide shall be discharged except into a licensed barge and at such places as the Authorities approve. Carbide shall only be carried in hermetically closed tins and no delay must take place in removing the Carbide to a properly licensed wharf.

HAZARDOUS SUBSTANCES.

From a fire point of view there are a number of substances that are considered non-hazardous and yet require very great care in storage.

(*a*) The following are Poisonous and must be kept away from foodstuffs—

Aconite Root and Powder, Ammonium Fluoride, Arsenic, Barium Carbonate, Barium Chloride, Barium Hydrate, Barium Hydroxide, Belladonna Root, Cobalt Acetate, Corrosive Sublimate, Mercuric Chloride, Oxalic Acid, Potassium Cyanide, Potassium Ferro-Cyanide (Red Prussiate) and Potassium Prussiate, Santonin, Sodium Ferro-Cyanide, Sodium Prussiate, Sugar of Lead, Tartar Emetic.

(*b*) Must be packed in tins or bottles in cases—

Olive Oil, Salad Oil.

(*c*) Must be packed in tins in cases or in screw stoppered metal drums—

The following oils—Aniseed, Argo, Attar of Roses, Bay Camphor, Cassia, Chalmoogra, Cinnamon, Citronella, Essential (other than mentioned), Eucalyptus, Lemon Grass, Lime, Orange, Sandalwood, Sassafras, and Peppermint.

(*d*) Must be packed in tins in cases—

Bronze Powder, Proprietary Manures.

(*e*) Must be stored in dry places—

Calcium Carbonate, Calcium Chlorate, Sodium Silicate.

(*f*) Must be packed in iron drums—

Glycerine.

(*g*) Must be packed in tin-lined casks—

Cod Liver Oil.

(*h*) Must not be in the same building or store as Acids, Alcohol, Organic Matter, or Foodstuffs—

Potassium Bichromate, Sodium Bichromate, Sodium Chromate, Sodium.

(*i*) Must be stored in Fireproof vaults or stores only, and also in tin cases—

Cocoanut Oil, Ground Nut Oil, Pea Nut Oil, Vaseline, and Wood Oil.

(*j*) Must have special attention and should be stored as directed by the Insurance or Wharf Authorities—

Copra, Molascuit, Molasses Meal.

Some hundreds of different kinds of goods are classed by the railways and dock authorities as hazardous from their point of view, and great care is required in the conveyance, wharfage, and shipment of such goods. It is necessary in all cases to ascertain what particular regulations are in force in a district before attempting to transport any hazardous goods.

A bottle of nitric acid which had been packed in sawdust and became broken caused a very serious fire in Paris.

The following TRADES, amongst others, are deemed hazardous. Those marked with an asterisk (*) are considered extra hazardous :—

Aerated Water Manufacturers.
Aeroplane Makers.
Apothecaries.
Bakers (with oven).
Basket Makers.
*Bedding Manufacturers.
Bookbinders.
*Boot and shoemakers by power.
Bottlers of Wines and Spirits or other Liquors.
Brass Founders.
*Brush Makers.
Calenderers and Finishers.
*Candle Makers.
*Cardboard Box Makers.
Chemists.
Cloth Cleaners.
Cloth Lappers.
*Coffee Roasters.
Confectioners, Retail (with candy stove, oven, or hot plate).
*Confectioners, Manufacturing.
Copper Smiths.
*Cork Burners.
*Cork Cutters.
*Curriers.
*Doping.
Drysalters.
Druggists, Retail.
*Druggists, Wholesale and/or Manufacturing.
Envelope Makers.
Fancy Goods Dealers.
French Polishers.
*Gas Singers.
Grocers.

*Ham Curers (if drying or smoking be done).
Hat and/or Cap Manufacturers.
*Hay and/or Straw Dealers.
Hot Pressers.
Indiarubber and/or Guttapercha Dealers.
Ironmongers.
*Japanners.
Laundry Keepers.
Letterpress and / or Lithographic Printers.
Marine Stores.
Munition Makers.
*Muslin Clippers.
Packers of Glass and/or Earthenware.
Painters.
*Paper Bag Makers.
*Paper and Cardboard Box Makers.
Paper Rulers.
*Paper Stainers.
Photographers.
*Playing Card Makers.
Plumbers and/or Gasfitters.
Preserve Makers.
*Rag or Waste Dealers.
*Rede and Heddle Makers.
Restaurateurs.
Rope Dealers.
Saddlers.
Sail Makers.
*Ship Chandlers.
*Soap Boilers.
*Spice Grinders.
Spirit Dealers.
*Stables, Keepers of Livery, and/or Contractors.
Stationers, Manufacturing.
Tanners.
*Tarpaulin Makers.
Tobacco and/or Snuff Manufacturers.
Umbrella Makers.
Upholsterers.
*Varnish Manufacturers.
Warpers and Winders.
*Waterproof Garment Makers.
*Waterproofers.
*Workers in Wood.

(20) **Rays of the Sun.**—The sun is responsible for a number of mysterious outbreaks of fire, which not infrequently are attributed to "spontaneous combustion." Its direct rays by their warmth, of course, facilitate all processes of oxidisation. When focussed on an object of an inflammable nature the incendiary results first discovered by that marvellous engineer, Archimedes, are obtained. These focussing media are often very innocent in appearance ; to cite a few every-day examples that would not be considered dangerous to the average laymen : a concave shaving mirror, a full water bottle of spherical form, a glass ball paper weight, a bubble in a pane of glass or a glass tile. Yet the concave shaving mirror is capable of fiercely concentrating the sun's rays on any object accidentally situated at its focal point, whilst both the water bottle and the bubble in the glass form a double convex lens of equal incendiary potentiality. Defective glass in the form of sheets or tiles is dangerous when used for lighting lofts where combustible materials are stored. During warm weather the goods become appreciably heated, and therefore ready to respond rapidly to the effect of a focussed ray. If the glass is roughly ground or is externally covered with any semi-opaque, tenacious paint—white for preference—so as to admit only diffused rays to what is in reality a chance lens, all danger is eliminated.

Again, direct sunlight will start off certain chemical reactions, such as the combustion of phosphorus in bulk, and the explosive union of chlorine with hydrogen, methane, or acetylene. Even common "Bleaching Powder," when exposed to direct sunlight, liberates free oxygen, which in its turn is, of course, ever ready to favour any tendency to combustion. Exposed to the sun's rays, barrels, or indeed any form of receptacle containing volatile liquids which give off inflammable vapours, become dangerous. The pressure generated may burst these receptacles or cause leakage of vapour, which will wander forth in search of an unprotected flame. Solid hydrocarbons, such as naphthalene and camphor, also give off inflammable vapours, and must not, therefore, be overlooked. Cylinders of compressed gases have

their pressures enormously increased by exposure to strong sunlight, and if it is not practicable to keep them under cover, they must be sprayed with water to keep down the temperature.

(21) **Arson and Incendiarism.**—The term "arson" in Common Law means "the malicious and voluntary burning of the house or premises of another." That definition, however, was widened by an enactment called the Malicious Damages Act, passed in 1861, and made synonymous with incendiarism, that is to say, the unlawful setting fire to, and burning of any house or premises with intent to injure or defraud.

The firing must be wilful and malicious, so it follows that no mere negligence or mischance can amount to arson or incendiarism unless it should happen that the offender in the act of committing a felony, such as burglary, accidentally sets fire to the house. Loss of life under similar circumstances would involve a charge of wilful murder. The crime of arson was formerly of less frequent occurrence than it has been since the establishment of Fire Insurance in 1690.

The strong motive of felonious fire-raising nowadays is the temptation offered by the Insurance money.

Cases of fire due to arson or incendiarism are not often proved in England; but on the Continent and in America, a poorly paying business often ends in all redeeming fire, which sometimes unfortunately overleaps its bounds and endangers the lives and property of innocent persons. This is especially the case with dwellings over, or at the back of, shops in congested areas. Fortunately, many incendiaries do not understand their business and therefore fail, or, succeeding too well, reveal their action, and thus fail doubly. Every fire has an origin and this beginning should be diligently sought for, and established beyond doubt, avoiding hasty first-conclusions.

As stated in Chapter II. In a report of the Fire Commissioner of New York to the Mayor, dated 31st December, 1912, it is stated that "the crime of arson is rampant in our city," and it is alleged that this state of affairs was due in a great measure to the granting by insurance companies of policies for considerable sums upon a diminutive amount of property. In one case 135 *different policies*, amounting to 127,500 dollars worth of insurance, were obtained, on property worth exactly three dollars and ninety-six cents ($3·96), the property consisting of a few trifling articles of household furniture. Figs. 95 to 102, taken from the report mentioned, will indicate some of the devices used. It may be asked what constitutes evidence in the prosecution for arson. The evidence must prove conclusively that the action was wilful and malicious. The Chief Fire Brigade officer should examine the site of every doubtful fire himself, find where it started and how it spread, and then, and then only, listen attentively to the "theories" of the generally numerous "impressionists"; separate the wheat from the chaff, and draw his own conclusions. Occasionally, and only occasionally, will the cause have to be classified as "unknown," but if a succession of fires of unknown origin take place, the inference is that a band of incendiaries are at work.

It is of the utmost importance that fire brigade officers should make a point of mastering thoroughly the principles of incendiarism, for occasionally a job of destruction by fire is so well arranged and innocent in appearance as to be very effective. In making an inspection, first take a careful walk,

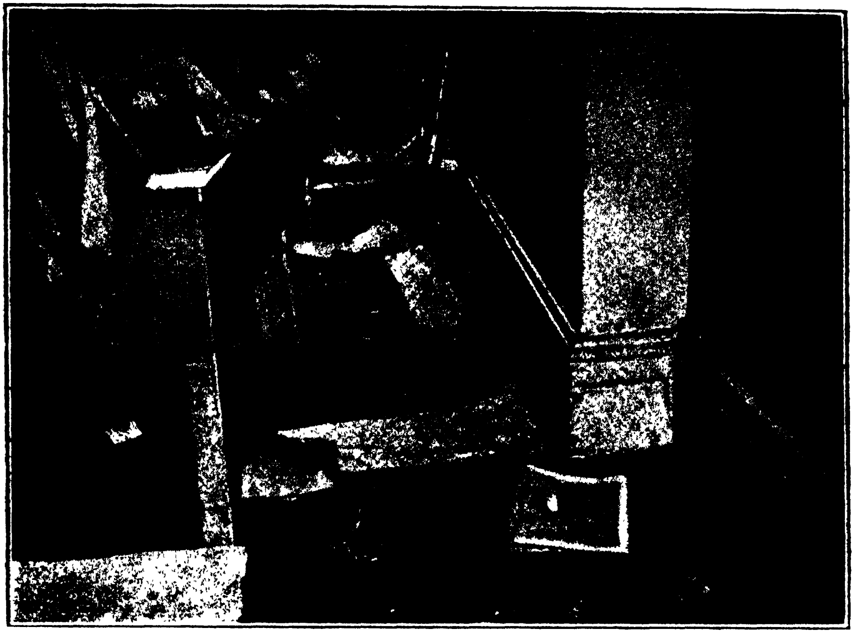


Fig. 95.—Candle on Oil-soaked Paper found in one case.

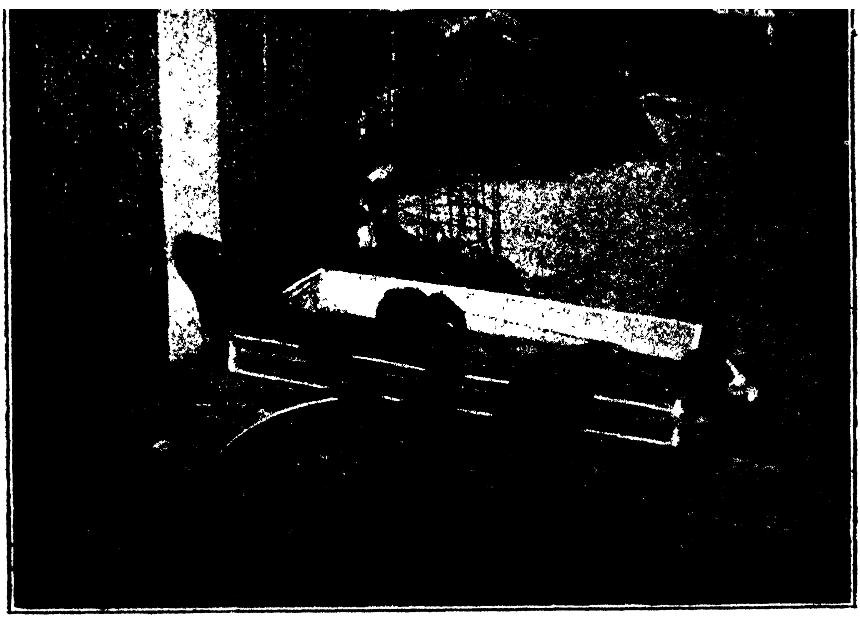


Fig. 96.—Box filled with Oil and Cloth Trailer (Oil-soaked) leading through wooden partition.

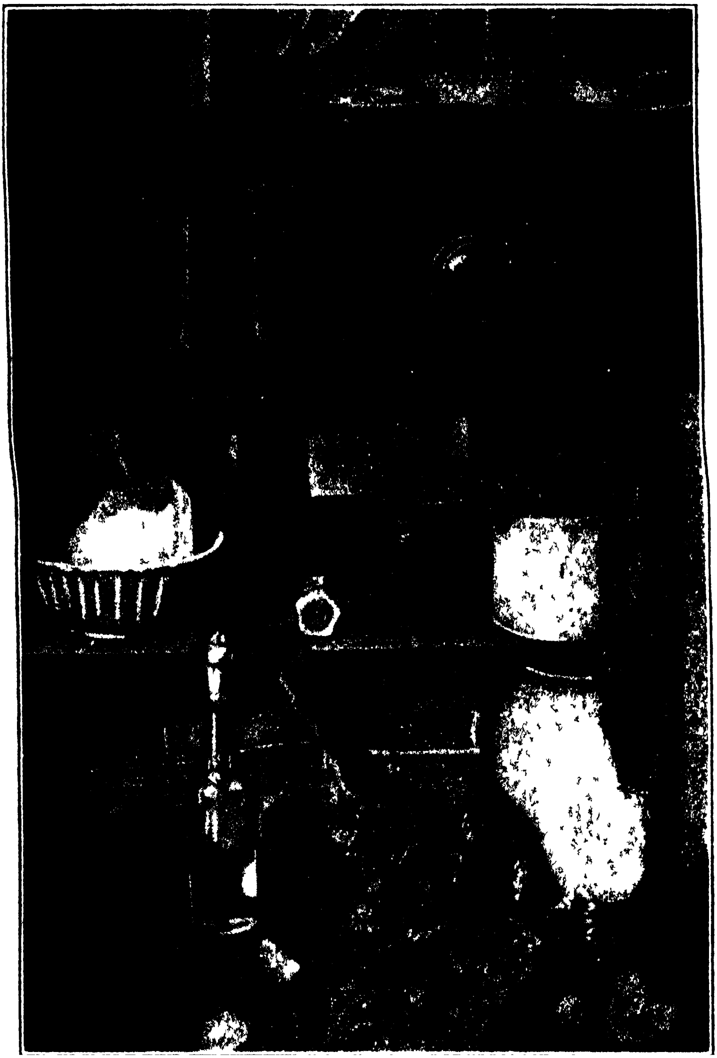


Fig. 97.—Showing bottle filled with Kerosene and Trailer leading from Shelf under Dresser in Kitchen.

Fig. 98.—Note Oil-soaked Trailers leading up into closet, also Matches on Floor.

Fig. 99.—Showing newspapers pinned to drawers and oil-soaked material in box with Candle.

Fig. 100.—Note Candle and Drawers filled with Paper soaked with Kerosene Oil.

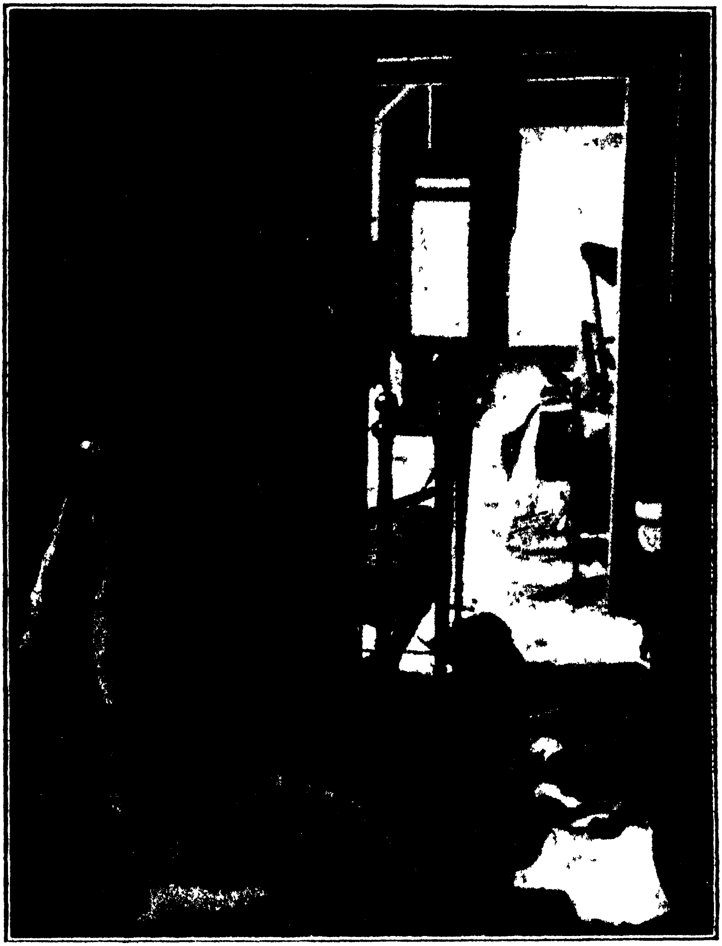


Fig. 101.—Incendiary Fire in Living Room. Note Oil-filled bladder in doorway, burst bladder on floor, Cotton trailer from handle of door. Thirty bladders used, each containing a gallon of Kerosene Oil.

unaccompanied, round the area, making note of any special dividing walls, open spaces, blind facades, etc., that should have prevented the spread of fire. Ascertain if the fire has been burning long before the call was given,

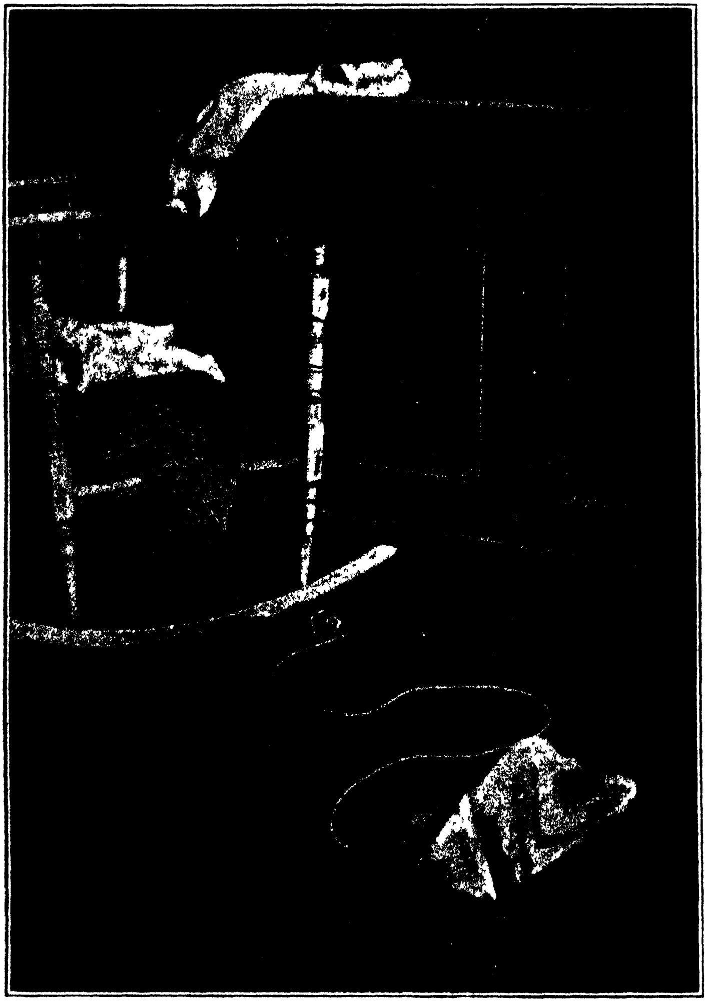


Fig. 102.—Giant powder bomb found in a Brooklyn house. Every gas jet in room was turned on. Mattress and paper oil-soaked.

and if so, whether the person who gave the alarm was interested in the safety of the premises.

This preliminary reconnaissance in conjunction with the knowledge of the direction and force of the wind will demonstrate where, and at how many points, the fire may have been started. The next series of observations

should be to ascertain if any holes had been broken through the floors, ceilings, or party walls, with a view to assisting the spread of the fire in a vertical and lateral direction. Broken windows and open doors all assist in promoting rapid combustion by allowing a good supply of oxygen to enter. Piles of inflammable goods generally leave a burnt residue marking the spot where they were placed. All parts of the building should be examined with a view of detecting the smell of paraffin, turpentine, or other easily combustible substance.

Evidence is of two kinds, direct and indirect, the latter being more commonly known and referred to as circumstantial, and it is with this latter kind that the fireman has most to do in cases of arson.

A Judge in the U.S.A., stated that "The commission of arson is as common nowadays as the convictions for arson are uncommon. It is a crime difficult to prove at best, but the more complete the burning, the less the evidence surviving."

Besides the survey recommended to be made after each fire, another and important point that may be useful as evidence for the Fireman, is that of "Tracks." It may happen that at, or close to, the scene of a fire, tracks of some individual are discovered and can be followed for some distance. These often prove helpful in ascertaining the culprit. Portions of clothing or other articles should also be looked for, and the exact position of any that are found should be noted by at least two persons, and a full description of the matter written by each. Again, it is well known that litigious or quarrelsome men are sure to have enemies, and often unscrupulous ones. Judicious inquiries should be instigated as to whether any threats have been made to burn the property; whether any fires from "unknown causes" have occurred either to the property in question or to any others, belonging to the same owner.

Examination should be made for any traces of robbery, and as to the likelihood of subsequent burning to cover traces of the crime.

Premises that have been a nuisance to the neighbourhood, and in the opinion of the adjoining owners, have impaired the value of their property, may have invited incendiarism on the part of malicious boys or unprincipled persons.

Buildings that were unoccupied should be examined for evidence of occupation by tramps or vagrants.

In all cases in which a suspicion of Arson or Incendiarism occurs, the utmost care and tact is required, as a false charge, or even a true one that cannot be substantiated, may involve the Fireman in a heavy claim for damages.

CAUSES OF FIRES IN PREMISES AND THE RISKS RUN IN EMPLOYING VARIOUS MATERIALS THAT MAY BE CONSIDERED HAZARDOUS.

Acetylene Engineers.—See p. 180.

Acid Manufacturers.—Furnace and burners, spilled acid on fibrous material.

Agricultural Implement Manufacturers.—See Metal Workers.

Ammonia Manufacturers.—Ammonium cyanide, which volatilises at 97° F. (36° C.), is inflammable. Ammonium nitrate explodes by percussion or when heated to 158° F. (70° C.). Very unstable.

Ammonia gas is usually pronounced incombustible and incapable of being

exploded when mixed with atmospheric air, but research and experience have shown that this is not altogether true. A mixture of ammonia gas and air can be exploded if it contains from 16 to 27 per cent. of ammonia, and some of the explosions that have occurred in large refrigerating plants subsequent to the liberation of considerable quantities of ammonia may possibly have been due to the ignition of mixtures of this kind by means of the arc lamps which have in most cases been in use in rooms where these accidents have occurred.

Ammunition Dealers and Manufacturers.—See p. 163.

Analysts.—See Chemical Manufacturers.

Artificial Flowers, when treated with a celluloid or similar varnish, require great care. Risk, naked lights and dirty rooms.

Asphalt, and **Bitumen,** when heated give off inflammable compounds, which if allowed to ignite may involve the premises.

Auctioneers.—See Offices, Stores. Every care is required in Auction Rooms that inflammable materials are not concealed in goods stored, and that damp or oily fabrics are not admitted, and that smokers have not left any lights or smouldering remains.

Automobile Engineers.—See Motors.

Bag Manufacturers.—Heating adhesive material and drying stock.

Bakers and Confectioners.—Overheating of ceilings over or too near ovens, and empty sacks and dust.

Basket Manufacturers.—See Builders, Cabinetmakers, and Drapers. If blind persons are employed much extra care is required for their protection and means of escape.

Bazaars.—See Drapers.

Bedding and Mattress Manufacturers.—See Drapers. Risks, dust and naked lights.

Billposters.—See Stores. Oil paper and paste-making stoves.

Biscuit Manufacturers.—See Bakers. Extra care required to see the drying ovens are kept clear of sacks or any other combustible material.

Blacksmiths and Farriers.—Sparks from chimney, and hot metal fliers.

Boarding Establishments.—See Hotels, etc., Chap. xvii. Badly fitted gas stoves, spirit lamps for heating curling irons, smoking in bed. Supply plenty of metal ash trays for cigarette ends and spent matches.

Boat Builders.—See Builders. Extra care required with tar and boiling pitch.

Bookbinders.—See Lithographic Printers.

Boot and Shoe Factors.—See Factories. Stoves and danger from celluloid and burning cuttings.

Bottle Merchants.—See Retail Shops. Extra care with straw and packing goods.

Brewers.—Explosions of dust in Malt Mills, also see Factories, Motors, Bottle Merchants, Joiners. Extra care with stoves for melting wax.

Bronze Powder Manufacturers.—See Printers, and p. 184.

Brush Makers.—See Factories. Extra care with pitch, oil, and drying stoves.

Builders and Allied Trades.—See Chap. xvi. and Metal Workers. Dilapidated roofs, floors, and buildings generally; inefficient illumination and unprotected lights; no proper provision for workers' clothing; sawdust, oily waste and other materials not removed each evening, or allowed to collect in ducts and out-of-the-way places; holes in floors and direct unprotected communication between the various shops; lightning conductors missing or improperly fixed (see p. 156); heating by open grates, stoves, and flues or hot water pipes not properly protected; stocks of quicklime allowed to get damp; glue heating by gas rings not upon stone slabs, and with rubber tubing connected; drying rooms not isolated; jars of spirit used in French polishing kept uncorked in heated rooms or near open fires or lights; stoves not ventilated and isolated; oils, fats, and spirits not kept in stoppered metal receptacles, and the stores allowed to be used for hoarding any spare material. Inspection by a responsible person should be made from time to time, and regularly after work is over before locking up. All timber yards should be kept clean, and the ground clear of grass and weeds.

Butchers and Tripe Boilers.—Fires to boilers. In the event of the refrigerating apparatus being out of order, there is considerable danger of life due to the leakage of the ammonia or its fumes.

Cabinetmakers.—See Builders.

Cap and Hat Makers.—See Drapers. Extra risk where spirit of any kind or celluloid is used.

Carbide of Calcium (Makers).—See p. 180.

Carmen.—See Hay and Straw Dealers. Extra risk, inflammable materials in goods during storing or transit.
Carpenters.—See Builders.
Carriers.—See Carmen.
Case Makers.—See Builders.
Caterers.—See Hotels.
Celluloid Goods Manufacturers.—See p. 135.
Cement Manufacturers.—Overheat of furnaces, and coal grinding mills.
Chair Makers.—See Builders.
Chemical Manufacturers.—See p. 183. Extra risk, boiling and heating inflammable mixtures, chlorates, nitrates, ether, alcohol, and many other dangerous materials.
Chemists.—Retail. See Chemical Manufacturers, Volatile Liquids, and Celluloid Goods Factories. The large spherical show bottles of coloured solutions act with the sun's rays as burning glasses.
Cinemas and Cinematograph Stores.—See p. 135 and Chap. xvi.
Clothiers and Outfitters.—See Laundries. Benzine and solvents used for cleaning.
Coach Builders.—See Builders.
Coal and Coke Merchants.—See pp. 151 and 159.
Colour Manufacturers.—See pp. 140 and 183.
Comb Manufacturers.—See Celluloid.
Concert Halls.—See Chap. xvii.
Contractors.—See Builders and Motors.
Coopers.—See Builders. Fires for expanding iron bands and wood steeping apparatus not properly extinguished.
Cork Merchants.—Burning refuse.
Corn Merchants.—See Hay and Straw Dealers. Overheat of grain. See p. 145.
Cotton Goods.—See p. 57 and Chap. v., p. 144. Temporary lighting, foreign material, dust, and sparks from machinery.
Curriers and Tanners.—Undue warming hides for greasing; heat in the dung pickle; application of lacquer varnish; overheat of tan; tan dust; oily and fatty waste; use of benzol and alcohol; quicklime: the haphazard mingling of the various tanning agents; tawing and chamoying (Morocco leather) by oiling and piling hides in heaps to undergo a process of fermentation in order to oxidise the fat; boiling of the bones, scraps, etc., to make glue.
Decorators.—See Builders.
Drapers.—Fancy and celluloid goods near lights, waste material and ironing, temporary fittings. Blocked exits and piles of goods that may be overturned may endanger life.
Druggists.—See Chemists.
Dyers and Cleaners.—See Clothiers.
Electrical Supplies.—Charging accumulators, short circuit of current, lamp shades near lights, use of hot wax, shellac or paraffin, and drying rooms.
Enamellers.—Overheat of drying stoves.
Envelope Makers.—Boiling glue and drying rooms.
Exhibitions.—See Drapers.
Explosive Manufacturers.—See pp. 164 and 183.
Export Packers.—See Builders, Auctioneers, and Stores.
Factories and Workshops.—See Chaps. xvi. and xvii. Insufficient lighting and ventilation, dirty and untidy rooms (bad housekeeping), stairways, doors and passages blocked with goods, and the stock so placed that it can be easily knocked over and the gangway blocked, furnaces, stills, and condensers with their flues dirty or out of repair, mixing goods of various kinds, such as acids and vegetable material, oils and fabrics, chemicals avid for oxygen and oxygen carriers, such as chlorates, peroxides and nitrates, waste materials and rubbish allowed to accumulate in cupboards, behind hot-water pipes, and out-of-the-way places, packing cases, straw, paper, old bags, etc., stored near sheds or combustible stock. Smoking and the use of naked lights.
Fancy Box Makers and Goods Trades.—See Drapers, Envelope Makers, and Stationers.
Farmers.—Overheating of Corn and Fodder stacks, Manure heaps. Nitrate of Soda bags, Steam Engine, Smoking, Chimney on fire, Lack of cleanliness particularly between stacks, Drying Hops, Unprotected Lights, Lamps kicked over by Cows when being milked.

The name and locality of the nearest fire brigade and how to summon them should be posted in a conspicuous place. Provide plenty of buckets, tarpaulings, and know how and where to get water.

Fish Curers and Fried Fish Shops.—Overheat of smoke stoves, insecure hangings, fat boiling over, flues worn out or burnt through, and overheated flues.

Floorcloth Manufacturers.—Boilers for oil, wax, etc., spontaneous combustion in hanging and drying rooms, coating and grinding machines, burning rubbish, static electricity.

Flour Mills.—See pp. 149 and 153.

Forage Merchants.—See Hay and Straw Dealers.

Founders.—See Blacksmiths and Iron Founders.

French Polishers.—See Builders.

Furriers.—Overheat of stoves, spirit vapour, dirty drying rooms.

Galvanizers.—See Blacksmiths, and overheat of melting pots.

Gas Singers and Cloth Pressers.—Overheat of materials.

Glass Works.—Defective furnaces, sparks, hot glass, portable lights, packing risks.

Glovers.—See Drapers. Cleaning and spirit vapour.

Glue Merchants.—See Curriers. Haphazard mingling of any oily or fatty substances, sodium sulphide, tan, hair, or hide waste.

Gramophone and Record Trade.—Overheat of stoves, dangerous solvents, vapour from materials being heated, packing dangers.

Grocers, Coffee Roasters.—Grinding machines, portable lights, dust from roasted husks and overheat of roasting plant.

Gunsmiths.—See p. 163.

Hairdressers.—Unprotected lights, heating irons, spirit from hair-washes, drying ladies' hair after cleaning with spirit.

Hatters.—See Drapers, Furriers, and Glovers, also dust from fur, use of celluloid in finishing straw hats and feathers.

Hay and Straw Dealers.—See p. 143. Dust from chaff cutting, damp fodder, smoking, portable lights.

Hops.—See p. 149. Portable lights.

Hosiers.—See Drapers.

Hospitals.—See pp. 449 and 454 and Chaps. xvii. and xviii.

Hotels.—See p. 449 and Chaps. xvii. and xviii., also offices, shops and stores.

Hot Pressers.—See Gas Singers and Hatters. Gas heaters and boilers.

Incandescent Mantle Makers.—All factory risks and collodion.

Indiarubber and Guttapercha Manufacturers.—It is the carbon disulphide or petroleum ether—*i.e.*, sulphur solvents—that are very dangerous. Textiles treated with most rubber solutions give off explosive vapours when drying. Static electricity.

Ink (Printing) Manufacturers.—Lamp black of a very fine grade is sometimes prepared from acetylene, a process that is dangerous. The oils used are of a nature that decomposition of cleaning waste becomes a source of danger.

Iron Founders.—See Blacksmiths, and the danger from explosion due to running hot metal into damp moulds.

Ironmongers.—See p. 163. Explosives kept upon the premises, oils, packing materials.

Jewellers.—Workshop and packing dangers.

Job Masters.—See Hay and Straw Dealers, also Blacksmiths.

Joiners.—See Builders.

Lace Manufacturers.—All factory risks.

Lacquer Manufacturers.—All factory risks, and volatile liquids. See Builders.

Laundries.—Position, and obstructed exits, stoves for irons or drying, if gas-heated flat irons should have proper stands and sound tubing, if electric-heated, wires undamaged, and a red light showing when the current is on. No rubbish about.

Lithographic Printers.—Printing ink, volatile liquids and drying rooms, oily waste, and sweepings left about, heating and drying stoves, use of varnish and dryers.

Marine Stores.—Spontaneous combustion of oily and damp goods, smoking, temporary lighting, and heating stoves.

Meat Salesmen.—See Butchers and Tripe Boilers. Electric short circuit firing, cold stores, greasy wrappers.

Metal Workers.—Storage of oils, acids, oily steel chips, dilapidated roofs, floors, etc., position of and flues from forges, furnaces and ovens, heating oil for tempering, ovens for lacquering, Japanning and varnishing, air pressure sprayers, gas burners and tubing for soldering and heating, the buffing machines not properly cleared of dust

that may fire spontaneously, non-removal of sawdust, oily waste, etc., improper storage of oils, fats, spirits, varnishes, etc., workshops not properly cleaned after each day's work is over. Sparks from forges, chimneys, and flues.

Munition Makers.—See explosions, p. 163.

Muslin Clippers.—See Drapers.

Millers.—Friction of machinery, dust, short circuit of electric light, gas flame, overheat of drying rooms, damp sacks.

Milliners.—See Drapers.

Millwrights.—See Builders and Blacksmiths.

Motors, Works, and Garages.—Unprotected roof and inflammable buildings, floors defective and absorbent, drainage direct into sewer, naked lights, all the various risks of builders and metal workers, furnaces, and drying ovens, petrol for cleaning, and air pressure sprayers, soldering iron heaters, oily rags and waste, insecure electric switches. Accumulator charging. *Smoking.*

Musical Instrument Makers.—See Builders, Metal Workers. Glue-heating stoves.

Offices, Retail Shops, and Stores.—See pp. 57-144 and Chaps. xvii., xviii., and Boarding Establishments. Lifts and stairs not protected from other risks. Rubbish in cupboards, wicker waste paper baskets, no metal trays for cigarette ends, etc., gas rings for boiling kettles on combustible stands and with rubber tubing.

Oil Merchants.—See p. 171 and Storage, Builders.

Oilmen and Domestic Stores.—See p. 180 and Chemists, Drapers.

Owing to the combustible nature of the stock the greatest care is necessary.

Packing Case Makers.—See Builders, Lithographic Printers; also see no accumulation of waste material is allowed.

Painters.—See Builders.

Paper Bag and Box Makers.—Stoves, naked lights, and dirty rooms.

Photographers.—Celluloid films, how used, and the lights being left on in the enlarging lantern; also where spirit is used for rapid drying, as in the case of Press work.

Piano Manufacturers.—See Builders.

Plumbers and Gas Fitters.—See Builders. Special risk, portable braziers.

Printers.—See Lithographic Printers. Spontaneous combustion of greasy cloths, carelessness in handling benzine, and dirty state of premises.

Rag and Waste Dealers.—See Marine Stores.

Restaurants.—Defective and overheat of flues, gas and electric heaters placed upon metal coverings to timber or inflammable material, fat boiling over, refuse not removed.

Rubber Goods.—The principal dangers are the use of the solvents used in jointing, and in the drying rooms. See India Rubber Manufacturers.

Sack and Bag Manufacturers.—Jute, hemp, cocoa fibre, and all similar materials are subject to self-ignition if any animal or vegetable oil is present. A rise of temperature greatly assists spontaneous combustion.

Saw Mills.—See Builders.

Shipbuilders.—See Builders, Metal Workers.

Ship Chandlers.—See Oilmen and Marine Stores.

Silk.—Silk burns with difficulty, the substances with which it is loaded are often of a dangerous character, and when lead picrate is used especially so. The loading may get rubbed off, and accumulate in some part of the mass, and there constitute a centre of ignition. Artificial Silk when made from cellulose or from nitrocellulose requires care, especially the latter, owing to the dangers inherent in nitro-compounds. Should any quantity of dust arise from artificial silk, more particularly in presence of a naked flame, extremely violent dust explosions may be expected. The main risk appears to be attached to the volatile solvents employed in the process of manufacture of artificial silk.

Skin Dressers.—See Curriers.

Soap Boilers.—When rendering fat containing moisture it readily boils over and catches fire. The danger from the resins, benzol, ether, oil of turpentine, varnish, alcohol, oils, and ethereal oils, when used at temperatures above the ordinary is considerable.

Spice Grinders.—See Millers.

Stables.—See Hay and Straw Dealers.

Stationers.—See Drapers, Lithographic Printers.

Tanners.—See Curriers.

Tarpaulin Makers.—See Sack and Bag Makers, and dangers from tar boiling over.

Theatres.—See Chap. xvii.

Timber Merchants.—See Builders.

Tobacco Trades.—Tobacco, if not sufficiently aerated during the fermentation process, may heat to the point of carbonisation; it is seldom that it does so as to take fire, but carbonisation entails the loss of the all-important aroma, and water causes great damage. The danger is in the dryers and drying rooms.

Turkish Baths.—Carbonisation of sawdust, used for insulating and consequently near hot wall pipes, etc., and also woodwork used in the construction of ceilings of hot rooms to which metal ceiling plates may be attached.

Upholsterers.—See Builders and Drapers.

Varnish Manufacturers.—The building should be only of one storey, well built and isolated. The dry colours and lamp black are very prone to spontaneous ignition. Inflammable vapours, colour grinding and drying, rosin and varnish boiling, are the principal causes of fires.

Waterproofers.—See Varnish and Rubber Goods and India Rubber Manufacturers.

Wharfingers.—All Storage. See Chaps. iv. and vi.

Wheelwrights.—See Blacksmiths, Builders, and Coopers.

CHAPTER V.

SHIP FIRES.

SHIPS are of so many kinds and sizes that it is difficult to draw a line between one class and another, but there are, however, some things in common.

A fire in a ship at sea must be considered as one of the worst catastrophies that can be conceived, and although, through the care and intelligence of the sailors, the percentage of ships totally lost by fire may not appear large, yet much can and should be done to reduce it.

For a graphic account of a fire at sea the reader is referred to a small book by A. Spurgeon, describing the loss by fire of the S.S. *Volturno* with a death roll of one hundred and thirty-six, 9th October, 1913. In this account the desperate situation of a ship on fire in heavy weather is well dealt with.

Another disaster, but under different circumstances, was the burning of the *General Slocum* in the East River, New York, on the morning of Wednesday, June 15th, 1904.

This huge wooden vessel, constructed with deck over deck. was considered one of the best, as well as one of the largest, passenger boats in the district.

The number of persons on board will never be known, they were principally women and children ; a thousand bodies were recovered from the river.

When passing through a narrow passage known as " Hell Gate," the cry of fire was heard from below, and in less than five minutes the whole ship was involved.

As it was impossible to beach the ship in the Gate owing to the rocks on both sides and the swiftly running tide, efforts were made to reach the nearest available point, a mile distant ; the vessel was burnt to the water's edge in half an hour.

It was stated the crew, realising the danger, tried all they could to restore calmness. How serious was the fire and panic is best explained by the fact that after the journey through " Hell Gate " the course was marked by floating bodies of persons who had jumped overboard. The arrangements on board for the extinguishing of fire were afterwards stated to be quite inadequate. The majority of the crew had never been drilled in the use of the fire hose, and this is also stated to have been unreliable. The life belts and life buoys were stated to have been useless ; even the lifeboats could not be used.

Ships, like buildings, have undergone great changes during the last sixty years. Not only have they changed in design and in the materials used in their construction, but they have enormously increased in size and in the character of their trade. Wooden ships that were the boast of the East Indian trade have almost ceased to exist. They were never more than

3,000 tons register, whereas the steel ships of our day are as floating towns compared with these earlier vessels.

Ships can be divided into three classes :—

(*a*) Cargo carriers,
(*b*) Those engaged solely in Passenger Traffic, or
(*c*) A combination of both.

The first class would include all that go by the name of "tramps"—*i.e.*, those which do not trade on a regular route but go from any port to any port. The second class is the large mail liner, and the last mainly comprises the slower liner or larger cargo boat. This is really only a very rough classification, for ships, like buildings, may change their uses, and precautions and safeguards proposed for one class of trade may be in need of augmentation or rearrangement in another.

Safeguards are also capable of classification, in as much as they may be—

(*a*) Administrative, (*b*) Constructional, or (*c*) Protective.

To deal with any of these involves the consideration as to how fires occur on ships, and any enquiry into the causes of fires reveals the fact that the contents of holds are responsible for the more serious, and therefore reported, ship fires.

A Parliamentary return of shipping casualties and loss of life for the four-and-a-half years, 1st July, 1914, to 31st December, 1918, compiled from reports received by the Board of Trade, which does not include casualties directly due to enemy action, states that 915 vessels (1,048,498 gross tonnage) were totally lost by marine casualty, of which 26 were due to fire—about 3 per cent. Of the 26 burnt in the 4½ years under review, 8 were due to spontaneous combustion of coal, 9 to petroleum spirit, 2 to overheating of cargoes of steel turnings, 3 unknown, and 1 each to flour, whale oil, timber, and tobacco.

Damage by fire was done to a larger number of vessels, but the return only gives the casualties in which loss of life occurred. These numbered 38 made up as follows :—General cargo 17, spontaneous combustion of coal 8, petroleum spirit 4, cotton 2, and 1 each to rum, explosion of acetylene gas, crude oil, lime, nitrate of soda, carbide of calcium, and overheating of stokehold.

A further return of fires which were reported as occurring on British Ships from August, 1919, to August, 1920, gives particulars of 242 fires, and detailed reports are given upon 144 of these fires. Coal in bunkers or holds was responsible for 75 fires, of which 3 were of a suspicious nature, and 1 due to coal gas explosion.

The actual cause of the fires could not be found in every case, but there was no reason to consider they were other than spontaneous combustion, except in 5 cases. The 1 due to explosion occurred through lack of surface ventilation.

Evidence points to the fact that where partly empty bunkers are filled with coal, the coal which has been left in the bunkers is liable to become overheated and to fire.

The return also gives 39 cases where fire was due, or probably due, to spontaneous combustion.

Nearly all the fires occurred in the bunkers. These are situated near the stokeholds, and are exposed to the heat therefrom, which would naturally hasten the process of spontaneous combustion.

Some coal appears specially liable to spontaneous combustion as exemplified by the fires on 4 ships. The coal in all 4 cases came from one colliery.

Source of Coal in which Fires occurred.

American . . .	22	Canadian, . .	2	Scotch, . . .	2
South African, . .	8	Welsh, . .	15	Asiatic, . . .	7
English, . . .	21	Australian, . .	4	German, . .	1

Note.—Where coal from different sources has been in the bunkers when fires have occurred, and no mention is made of the coal that actually fires, all the various kinds are included in this list.

In two ships, both originally German steamers, the coal had been in the bunkers for some years; the next longest period during which the coal had been on board was 6 months. Otherwise, the period of heating until fire actually occurred appears to have been between 3 weeks and 3½ months. There are exceptional cases, however, viz., one in which the bunkers were coaled after having been swept out, and a fire broke out in one bunker in 4 days' time, and in another bunker a few days afterwards : another in which the fire occurred whilst the vessel was still in the coaling port ; and in one case the cargo of gas coal took fire on the short voyage from Newcastle to Southampton.

Bunkers should be tight, to prevent air from passing through the coal and thus providing oxygen, the absorption of which is attended with overheating. Unless the heat of absorption and oxidation can be carried off as quickly as it is generated, overheating will occur. Coal remaining in bunkers should be moved to where it can be used first. Small coal is more liable to spontaneous combustion than large coal.

It might be added that all coal is, apparently, liable to spontaneous combustion. When it does occur on board ship, it is probably due to fortuitous conditions in regard to the rate and supply of air (oxygen), and the rate of escape of the heat generated. A slight change of the conditions either way may mean the difference between overheating and the absence of it. Hence a ship may carry coal in the bunkers without fires occurring over a long period of years.

Table of Commodities in which Spontaneous Combustion occurred, or is supposed to have occurred.

Commodity.	Number of Fires.	Commodity.	Number of Fires.
Copra, ...	2	Nitrate, ...	2
Sugar in Bags, . . .	6	Lime and Straw, . .	1
Cotton Waste, . . .	1	Hemp and Jute, . .	7
Cotton Bales, . . .	4	Old rope in Bales, . .	1
Cotton Seed, ...	2	Rags and Flax Waste, .	3
Cotton Seed and ground Nuts,	1	Rags and Linseed Oil, .	1
Oil Cake, ...	3	Sheepskins in Bales, . .	1
Coir, ...	2	Fish Guano, . . .	1
		General, ...	1

All the different commodities in this Table appear to require care in the condition in which they are shipped, in the manner in which they are bagged, and in the stowage. If stowed near heat, spontaneous combustion is accelerated.

Rags, hemp, jute, sheepskins, and cotton waste, if compressed and in oily or greasy condition, as some of the above cargoes were, may be expected to fire spontaneously.

Fire occurred in 26 of these cases when the vessels were either loading or discharging, or in a port of call, and 13 occurred while the vessels were at sea.

In some cases the cargo had been on board a longer period than usual owing to breakdown of the vessel's machinery, or delay in discharging in dock. The longer such cargo is kept on board, the greater is the probability of fire.

The report also mentions 42 fires which were due to causes ascertained or supposed to be carelessness. In thirty-six of these cases the vessels were in port loading, discharging, or laid up, when fire occurred. They do not include cases of carelessness where oil has taken fire. These are included below under "Oil Fires." Some of the commodities mentioned may have been liable to fire spontaneously, and the fires may possibly have been due to that cause.

The report further gives 39 miscellaneous fires, 29 oil fires, 4 fires due to supposed incendiarism, and 6 fires caused by short-circuiting of electric wires.

Administrative.—A Memorandum issued by the Board of Trade for the information and guidance of their Officers and other persons who deal with the shipment of goods of a dangerous nature in ships sailing from the United Kindgom, states :—

"From the standpoint of seaworthiness, all goods should be regarded as dangerous whose carriage on board ship may, by reason of their natural properties, involve special risk to the safety of the ship or of the persons on board. Such goods are, for example, those of a highly inflammable nature, those liable to spontaneous combustion either in themselves or in contact with substances stowed adjacent to them, substances which on exposure to air or moisture, etc., are liable to generate or emit explosive, poisonous or suffocating gases, and articles in which exposure to the temperatures likely to be met with on board ship may cause dangerously high pressures leading to explosions. In dealing with such goods, it is necessary to consider the nature of the substance both in itself and in relation to other substances stowed with it, the packing and method of stowing and the influences (*e.g.*, rough usage or high temperature in a hold or on deck in the tropics, etc.) to which it may be exposed.

"All dangerous goods that are not required to be marked 'Dangerous or 'Poison' should be marked with the words 'Special Stowage' in red letters not less than 2 inches deep.

"Dangerous goods should be stowed in well-ventilated compartments as far away as possible from engine and boiler room bulkheads and from living quarters, and these compartments should be separated off by efficient bulkheads. The goods should be stowed adjacent to, or in the hatchway, in such a manner as to be always accessible. They should not be stowed in

compartments below passenger spaces or compartments opening out into such spaces.

"Particular care should be taken when more than one kind of dangerous or inflammable goods is carried in the same ship, or when dangerous goods are carried in a ship carrying coal as cargo. The indiscriminate stowage on decks of dangerous goods and chemicals should not be permitted.

"In the case of Emigrant ships,* with the exception of naval and military stores conveyed by order of a Secretary of State, no dangerous goods of any kind may be carried without the special permission of the Board of Trade or an Emigration Officer.

"The various substances referred to in this Memorandum form a list of 46 pages of dangerous goods. When it is intended to carry any other doubtful substances or to use alternative methods of packing the case should be submitted through the Principal Officer for the Board's consideration."

But it is not to be supposed in proposing administrative safeguards that the contents of every bale and package can be detected as it is swung over the side into the hold. This may seem an easy matter, but those who have had any experience in dealing with cargoes know only too well the many opportunities there are for these considerations to be waived. Time is an important factor in shipping. For economy in working, the cargo should no sooner be out of the boat than another should be stowed. Even the Customs Authorities, with their great vigilance, know how easy it is to let packages escape them, and the crew cannot be expected always to detect dangerous substances such as those compounds containing a portion of their oxygen in a loosely combined state, known as peroxides. The majority of oxygen carriers are oxides, as are certain acids when supersaturated with oxygen, nitrates and chlorates. Oxygen carriers behave like this element itself, and exhibit the same dangerous properties. When the liberation of oxygen by these compounds is effected in an atmosphere of inflammable gases or vapours, or in direct contact with organic substances, like resins, ethereal oils, or mineral oils, and the temperature is merely slightly elevated, an immediate ignition of these substances may occur; and further, if the circumstances are favourable certain carriers of oxygen will ignite organic substances even at the ordinary temperature. No great reliance can be placed on administrative safeguards unless the regulations are accompanied with efficient vigilance. For regulations to be of any use they must be constantly dinned into the ears of those whose duty it is to carry them out. Rules as to the method of packing and storing of cargo cannot of themselves obviate fires, as everything depends on the heed and care paid to them. The value of notices "permanently" exhibited in the inevitable "prominent" position is often lost by such permanence and prominence being ignored through long familiarity, when of course they are forgotten at the critical time.

Again, sets of general regulations framed to cover a number of instances may by reason of their generality omit important warnings for particular cases

Most suggestions and recommendations involve the public "Notice,"

* An Emigrant ship is a ship which carries more than 50 steerage passengers upon any voyage from the British Isles to any port out of Europe and not within the Mediterranean Sea.

but unless there is some originality used in the design of these permanent instructions they become forgotten when most needed.

Inflammable materials are often very carelessly handled by passengers, who also use spirit lamps in their cabins. Flimsy decorations for balls and concert rooms are also frequently a cause of fire.

The important section which has not been touched upon in this chapter concerns spontaneous combustion. This is dealt with in Chapter I., but owing to the prominence which has been given to the subject by the academical enquiry which has been made at the instance of the Government, it may not be out of place to add a further word or two.

Speaking chemically, combustion is of course nothing but rapid oxidation, which by reason of its rapidity generates sufficient heat to cause the substance to catch fire. In order to create burning, oxygen must be present in sufficient quantity, and this can be supplied in many different ways, *e.g.*, free, from the air, conveyed by water, or occluded. Fortunately the instances of occluded oxygen in ordinary fires are few, celluloid being perhaps the most dangerous, because it contains sufficient oxygen to support its own combustion, and, so far as ship's cargoes in the hold are concerned, the oxygen supplied by free air cannot be large if the hatches are on and properly sheeted.

Combustion in vessels fitted for cold storage is often caused by the slight wetting of the paper or charcoal used for insulation. When fires occur in this way, they are very troublesome, and from its behaviour and the risk attaching to its use, such insulation certainly does not encourage adoption. Slag wool is often used, but is not preferred owing to its great weight. Cork is a good insulator, but rather more expensive.

Constructional Safeguards.—The safety of ships considered from this standpoint hits at some of the very commonest sources of fire and suggests strangely enough perhaps the most drastic of remedies. Shipbuilders as a class know well enough that in designing ships to a specified tonnage, the elimination of transverse sections is a real gain to them in the ultimate cubic space for stowage. This accounts for much of the opposition to the firemen's cherished remedy against the fire damage, namely, division of large compartments by the introduction of bulkheads. Yet such a procedure has been found, in the case of large warehouses and stores, to be the only really effective method of confining the limits of an outbreak.

The International Conference on the Safety of Life at Sea considered the questions of bulkheads, and recommended that "in parts of ship above the margin line there shall be fitted fireproof bulkheads which will serve to retard the spread of fire. The mean distance between any two consecutive bulkheads of this description shall not be greater than 40 metres (131 feet). Recesses in these bulkheads shall be fireproof, and the openings in these bulkheads shall be fitted with fireproof doors."

The "margin line" is explained in the Merchant Shipping (Convention) Act, 1914, as 3 inches below the upper surface of the bulkhead deck at the side—*i.e.*, the deck up to which the bulkhead comes—except the collision bulkhead which goes one deck higher. Some portions of the upper holds may be used for passengers.

Fire-resisting bulkheads and doors for the rapid division of the larger compartments on the occurrence of a fire are now provided in large passenger

vessels. Bulkheads should be arranged in the ship so as not to interfere with the escape of the crew from engine room, stokehold, and from the other lower parts of the ship. As many bulkheads as are compatible with the division of a ship into as many compartments as will not greatly affect efficient working, should be constructed. Other constructional safeguards may be found in the introduction of *fire alarms, sprinklers,* and drenchers*, though it is recognised that, unlike buildings, ships are not stationary and are subject to great extremes in temperature.

Further safeguards under the "constructional" heading would include the elimination of inflammable material. Panelling of any kind is dangerous on account of the cavities or flues which are formed behind it, and if the panelling is itself of an inflammable nature the danger is accentuated. Wherever possible, only incombustible materials should be employed. Curtains, blinds, and the like, should be of fire-resisting or treated material.

Protective Measures.—Losses by fire at sea, even in normal years, are very considerable, and the adoption of the most efficient means of preventing and extinguishing fires should be considered by the owners as real economy.

Owners should also see that extreme care and watchfulness is exercised in the loading, stowage, and discharging of cargo, as many fires are attributed to smoking and carelessness on the part of the men working upon the cargo.

In spite of all the precautions which have been devised for the prevention of fire, fires will still occur, and the net result is that whilst taking all measures to reduce outbreaks to a minimum, provision must still be made for the fire which will be bound to take place some day.

Under this head, therefore, it is necessary to place those appliances which would be employed in suppressing fires on ships. To some extent the constructional and protective measures overlap, for some suggestions could not be carried into effect without constructional co-operation. Reference has been made to the fact that serious fires nearly always break out amongst the cargo, but not infrequently the deck houses become the chief seat of the fire.

The work of suppression is not so easy as might be imagined, considering the vastness of the water supply which is at hand. Immediately the alarm is raised the fire squad should be reinforced by other members of the crew, and small appliances, wet blankets, extincteurs, or hand pumps, should be hurried to the scene. Hydrants should next be made ready for action. Everything should proceed on a set plan with as little fuss as possible. Care should be taken to see that the hydrants are sufficient in number and size for the ship in which they are fixed. If the fire is in the cabins or among material easily removable, it would be wise to cut a way around if it threatens to extend. If the fire is in a confined space, the use of a smoke helmet or proto-breathing apparatus would be useful to approach the seat. Certain men of the fire squad should be well versed in their use (see Chap. XII.).

If the hold is full of cargo which is well on fire, and there is no injection system, the only way to deal with the fire is to fill up the hold. In filling up the holds it is important to keep the ship upon an even keel, since any list tends to allow a portion of the space under the deck to be out of reach

* Congreve secured a patent for a sprinkler system for ships in 1812. See Fig. 127b.

of the water, and so permits the fire to continue as long as the fuel lasts. When possible, a ship on fire should be berthed at a quay where the depth of water is just sufficient to allow it to float, so that as the holds are filled the ship will settle down upon the bed of the harbour.

The introduction of the Radiotelegraph provides ships at sea with the means of sending a warning to the Authorities of Ports they are making for, and thus allow time for arrangements to be made for the reception of the ship, and a berth prepared where she can, if necessary, settle down without undue damage. If the berth is within the reach of cranes, the work of the stevedores in unloading is much facilitated.

A comparatively small fire in the confined space of a ship's hold will give off a large quantity of smoke that may contain gases which readily ignite. By the judicious use of a branch, particularly one with a spray, a draught may be caused to force the current of air in a direction that will allow of an entry being made into the compartment with the extinguishing apparatus.

Every ship with more than one hold or three cabins should be fitted with an efficient, reliable, and substantial automatic fire alarm so arranged as to give the Officer in charge early notice of any sudden rise of temperature in any part of the ship. This is not a costly matter. Early warning, and subsequent attention, will most probably prevent heat developing into a fire, and possibly confine a fire to a small area. The system in which small copper tubes filled with an expansive fluid are used admits of ordinary variations of temperature, but gives an alarm upon a sudden rise of 15° or 20° F. (8° to 11° C.). These tubes are so small that they are not noticeable, but they are quite efficient.

One system, which is well spoken of, consists of a dual arrangement of fire alarms and extinction pipes.

Upon any fire or undue heat being registered by a thermostat in the chart room or any other controlled position, the officer of the ship can, by means of small pipes, inject liquid carbon dioxide (carbonic acid gas), an every day article of commerce, into any part of the cargo space that is fitted with the apparatus. The pipes can be as small as half an inch (0·013 m.). Upon the liquid acid issuing from a pipe, it is converted into a heavy gas 500 times the volume of the liquid, which at the same time causes a fall in the temperature in the hold to below zero. Thus the pressure of the gas will displace the air with its oxygen content, and keep down the fire, while the reduction of the temperature will render the restarting of a fire unlikely.

One hundred cubic feet (2·8 m.^{3}) of gas can be condensed in the liquid state in a steel cylinder one foot (0·3 m.) long, and 3 inches (0·08 m.) in diameter, and a ton of coal contains air spaces equal to about 12 cubic feet (0·34 m.^{3}), so that one of these cylinders would have to be put in for every 8 tons of coal.

Another system advocated is the injection of carbon dioxide drawn from the furnaces of the stokehold into the hold on fire. This doubtless would extinguish any fire, but would require special arrangements to be made for its expulsion after the extinction of the fire.

As shown by the Board of Trade return (July, 1914, to December, 1918) the cause of fire in one-third of the ships burnt was due to spontaneous

combustion of coal, and petroleum spirit was responsible for over one-third of the ships burnt out.

A fire in the coal bunkers of a ship usually means removing some, if not all, of the coal. While the coal is being got out by the trimmers into the stokehold and up on deck, a line of hose should be lowered down one of the ventilators to assist in cooling the coal and gradually working it to the openings in the stokehold: another jet should be ready to cool down the hot coals as they fall to the place the men are clearing. By drawing the burning coals to the floor the fire may be extinguished without removing the whole stock.

Should the coal be small, there is a chance of the water from the top causing it to cake and form an arch, and on the coal underneath being removed, this becomes a danger to the men working there through the likelihood of its falling upon them. It is equally dangerous to work upon the upper side of a formation of this kind.

Where a cargo of petroleum spirit is on fire (and no system of foam is installed), it is best to get the ship into shallow water where she can ground, and then to fill up the compartments on fire with water. The damaged tins will, of course, allow the escape of their contents, which will in a comparatively short time burn away, and the remainder will cool down if carefully watched and sprayed with water.

Where fires occur in ships of general lading, the hatches should be kept well battened down until all hose is laid out, and stevedores and cranes ready to work out the cargo. When all is ready, the hatches should be quickly removed, and water played upon the cargo, and at the same time some of the goods removed in order that the Firemen may get their jets under the coaming, and thus keep the fire down sufficiently to allow the men to get on with the work of discharging the cargo. Great care must be taken that all cargo removed is placed at a distance from other goods until the danger of the fire breaking out again is past. This is particularly necessary with bales of cotton and jute.

Small fires will occur from time to time aboard ship. Such fires usually have their origin in one or other of the various store rooms; and combative work must be carried out with due regard to the nature of the contents. Thus, in the Engineer's store may be expected to be found very inflammable goods, such as oils, waste, tallow, paints, etc., the heat from which when on fire often renders the approach to the store difficult. The difficulties are accentuated in most cases by the fact that these stores are usually located in several out-of-the-way places, and also in the vicinity of the engines.

In the Lazaret the ships stores are kept, and a fire there is almost certain to be a smoky one; but it can generally be confined to its own particular room.

An emergency system of electric lighting—*i.e.*, one with a secondary generating plant—is now installed in may ships which can be brought into operation if for any reason the main supply fails. Such a system is undoubtedly a great help, but more as being a method of allaying fear or panic among the passengers than as being of any advantage to the staff.

Fires in the passengers' quarters are often difficult to locate owing to the chance that the outbreak may be in the lower cabins, the only approach to which is through long narrow winding passages.

As oil fuel is coming more into use on ships it may be expected that more oil fires will occur. The foam system places in the hands of firemen a handy and effectual means of dealing with oil fires (see Chap. XII., p. 361).

Precautions against Fire on Board Steam Ships burning oil fuel in the boilers have been carefully considered by the Marine department of the Board of Trade, and detailed instructions are on sale. These should be followed carefully.

Perhaps the measure of most practical utility would be to constitute certain members of the crew a fire picket, which should occasionally practice fire-drill.

The size and duties of the picket would naturally depend on the size and character of the ship. If it were purely a cargo carrier, a few deck hands would be all that would be required, but as the size and character of the ship approaches that of the big ocean liner, a more highly organised system would be necessary, involving a central call station, where a reserve of hand appliances for fire fighting should be kept.

In conclusion, it is to be hoped that much good may result from the coming into force of the regulations authorised by the Merchant Shipping Act, 1914, when they have been agreed to Internationally.

The instructions issued by the Board of Trade have had very careful consideration and cover most of the causes that lead to fires, but after all, it is upon the crew that reliance must be placed to keep the vessel clean, and also to make themselves fully cognisant with the method of using the fire-extinguishing apparatus. Every effort should be made to enlist the watchful attention and zeal of the men by making the drills instructive and upon no account should they be used for disciplinary purposes.

Regulations for the conveyance of Petroleum in the River Thames are set out on p. 134 of Chapter IV., and those relating to Carbide of Calcium at the end of the regulations of the L.C.C.

A ship on fire at sea sometimes plays strange pranks. When a fire is discovered, every effort should be made to stop all draughts, and this is generally accomplished by running the vessel before the wind.

All good captains know how to stop or check draughts in their own vessels, but there is no general rule on the subject, and certainly running before the wind, though most frequently attempted, is by no means always successful.

The extinguishing of a fire in a ship at sea will always depend upon the care that has been taken to keep the fire-extinguishing appliances in proper order, the discipline of the crew, and above all, upon the head and body of the man in charge.

CHAPTER VI.

EXPLOSIVES AND EXPLOSIONS.

THE explosions that firemen experience are mostly of the domestic or kitchen type. These explosions usually occur during a frost, and are due to the water in the pipes leading to and from the boiler becoming frozen, so that there is no outlet for the steam generated by the boiling of the water in the boiler, and consequently a very great pressure may be the result (see p. 48). The boiler cannot withstand such intense pressure, and bursts frequently with great violence. As has been mentioned elsewhere, about 1,642 cubic feet (45·3 m.^{3}) of steam are generated from 1 cubic foot (0·028 m.^{3}) of water at 212° F. (100° C.), and the stresses that are set up in a boiler under such conditions can, therefore, be readily appreciated. Occasionally there are explosions in the larger boilers and heating apparatus used in hotels, flats, offices, etc., as also in boilers and other steam vessels in factories. These are mostly insured, and are, therefore, periodically examined by the Assurance Companies' surveyors, who have obtained the necessary Board of Trade certificates. These inspections reveal any defects there may be, and as steps are generally taken to remedy such defects, explosions are rare. Such as do happen are mostly due to carelessness after cleaning or repairs, or to the fires being lighted before it has been ascertained that the water is free to circulate. Considerable damage is done to the structure of buildings by these explosions, rendering them unsafe, and great care should be exercised before any portion of the structure is removed. A small portion of brick or other material will often support some tons of debris, and if interfered with before the building has been properly shored, its consequent fall may cause greater damage than the original explosion. Fires are caused at the same time by portions of the contents of the fire-boxes setting light to combustible material upon which they may fall, or lights may be brought into contact with gas pipes that may have been fractured.

When any boiler explosion occurs a notice stating particulars must be sent within 24 hours to the Board of Trade by the owner or user, or by persons acting on his behalf. This does not apply to boilers used exclusively for domestic purposes.

Explosions due to an escape of coal gas in the street mains and bitumen gas generated in electric mains are dealt with on p. 132; these may be followed by other minor explosions under the street pavement at some distance from the primary cause.

Explosions due to an escape of coal gas in buildings are mostly caused by search being made for the point of escape with a naked light. Dealing with the cause of explosions, some explanation is necessary. "Flame can be defined as gaseous matter which has been raised to such a high

temperature that it is obvious to the eye. The luminosity of flame varies with the nature of the combustible substance and with the conditions under which the combustion takes place. A coal gas flame contains a host of unburnt carbon particles which are raised to a very high temperature and so give out a strong light. By mixing the gas with air before it comes to the nozzle of the burner, these carbon particles are completely oxidised and the flame becomes non-luminous. Such a non-luminous flame may, however, again be rendered useful for purposes of illumination by the artificial introduction of incombustible solids which are made incandescent by the heat of the flame."—(Philip). (This is the principle of the bunsen burner, and hence the incandescent gas mantle.)

Air is almost entirely composed of Oxygen and Nitrogen, Oxygen being the principal supporter of combustion. The difference between ordinary combustion and explosion being merely a question of the rapidity of the reaction. When either hydrogen or carbon is brought into contact with oxygen, the mixtures burn easily and rapidly with intense heat, according to the proportions of the mixtures. This is the underlying principle of the internal combustion engine. The petroleum spirit is vapourised and mixed in the carburettor with a correct proportion of the oxygen in the air, thus forming an explosive mixture; similarly in an ordinary gas engine the gas is mixed with the proper amount of oxygen for the same purpose. It is not a difficult thing to calculate the exact amount of air necessary to give the best mixture, but this scarcely comes within the scope of this work.

As will be understood by those conversant with the working of a motor car engine, if there is either insufficient or too much oxygen (or air) the mixture is such that the engine does not work owing to there being no explosion, or, it may be, a too feeble one. As the proportions of either hydrogen or carbon, or of both of these, vary in different liquids, gases, and vapours, so also the proportion of oxygen necessary to produce an explosive mixture varies. It may be laid down as a rule, not exactly invariable, but quite sufficiently so for general purposes, that the heavier a so-called gas explosion is, the more complete is the instantaneous consumption or combustion of the gas employed, and, consequently, the danger of fire ensuing is less; whereas in only light or partial explosions, there may be large quantities of pure gas in close proximity to the explosive mixture, and, if this takes fire, it burns with great fury, and communicates heat and flame to very considerable distances.

In the appendix will be found a table giving what is usually known as the "Explosive ranges" of different gases or vapours.

In a similar way may be explained the phenomenon of dust explosions. Whilst gases are made up of particles so small that they cannot be seen, dust is simply a quantity of separate particles, so that when a cloud of dust is in suspension in the air it resembles a mixture of gas and air, in that the particles are surrounded by the oxygen of the air ready to support the combustion of each. The results of a series of investigations made to ascertain the explosive properties of various dusts met with in ordinary industries are given under the heading of "Dust Explosion," in Chapter IV., p. 151.

Explosives in the everyday sense of the word must now be dealt with.

These come under the provisions of the Explosives Act, 1875, in which the term "explosive" is defined as follows :—

"1. Means gunpowder, nitro-glycerine, dynamite, guncotton, blasting powders, fulminate of mercury, or of other metals, coloured fires and every other substance, whether similar to those above mentioned or not used or manufactured with a view to produce a practical effect by explosion, or a pyrotechnic effect; and

"2. Includes fog signals, fireworks, fuses, rockets, percussion caps, detonators, cartridges, ammunition of all descriptions, and every adaptation or preparation of an explosive as above defined."

Marshall has explained an explosive as "a material which is capable of giving off a very large volume of gas very suddenly; at the same time it always evolves a great deal of heat. The gas which is thus suddenly formed tends naturally to expand, and in so doing, to overcome the resistance of anything which opposes the expansion. The sharp noise, which is always associated with an explosion, is due to this sudden evolution of gas. Heat is liberated at the same time and this produces a bright light; it also increases the expansion of the gas.

"A great many explosives are now known, and they may be divided into classes in various ways, according to their composition, their properties, or their uses. Some are single substances from the chemical point of view, such as nitro-glycerine or fulminate of mercury, others are mixtures such as gunpowder (black powder). In mixed explosives, some or all of the ingredients may be themselves explosive. Some explosives are very violent, detonating at the rate of several miles per second; these are termed high explosives. Others burn comparatively slowly and are used to propel a bullet or shell from a fire-arm. These are the smokeless powders. Black powder occupies a position between these two classes."

Some can be exploded directly by the application of a spark or by friction; gunpowder, if in a fine state of division, can be ignited by a spark, fulminate of mercury either by a spark or a blow, or by friction. Other explosives require a small quantity of an explosive of the last kind to send them off satisfactorily. High explosives are usually detonated by means of a detonator charged with fulminate. Smokeless powders are also generally provided with a small igniting charge of a more sensitive explosive. There are various special sorts of explosives used for special purposes. For instance, there are "safety" explosives used in coal mines. These are mostly high explosive mixtures so composed that they do not give a hot flame which will set light to "fire damp" or a mixture of coal dust and air. Fireworks are charged generally with slow burning mixtures resembling gunpowder more or less.

Of the various physical properties of an explosive, one of the most important is its sensitiveness. It must be sufficiently sensitive to be fired with certainty by the means to be used, but up to this limit the less sensitive it is, the safer, and therefore the better, it is. An explosive that is very sensitive to blow or friction is too dangerous for use. Other important properties are the power and violence of the explosive. The power is the quantity of work that an explosive can do. The violence depends not only on the power, but also on the time in which the energy is set free.

Manufactured explosives are so carefully regulated by law (see Chapter IV.), that accidents away from the factories when in store are not often met with.

Many persons consider that the keeping of explosives in towns and populous places should, in the interest of the public, be altogether prohibited; but in every civilised community it is necessary to balance the requirements of personal safety against those of important trades. All our laws and regulations are based upon mutual concession of the interests concerned. For this reason limited amounts of explosives are allowed to be kept even in the midst of cities in this country, and in most other countries of the world.

Effect of Explosion.—All explosives in common use are solids, and the actual effect of firing a charge is to convert in a moment the solid into an equal weight of gas and vapour struggling to occupy a space hundreds of times greater than that occupied by the original solid. An enormous pressure is thus exerted on the surrounding material, whether it be stone or merely air, and this pressure is immensely increased by the very high temperature at which the gases and vapours are produced, and may at the moment of maximum intensity amount to 100 tons per square inch, or more. The effect of this pressure may be imagined when it is realised that the maximum pressure in a shot-gun is as a rule limited to about 3 tons per square inch.

Dynamite striking Downwards.—This is a good opportunity to expose the very popular fallacy that dynamite strikes downwards. The pressure exerted by the sudden conversion of dynamite into gas must, of course, be equal in all directions, and the fallacy probably arose in the first instance from a comparison of the apparent effects of dynamite and gunpowder. Dynamite exploded on the ground leaves a hole, or crater, as it is called; gunpowder, unless strongly confined, forms no crater; the reason being that this latter explosive is comparatively so slow in its action that there is time for it to seek out and expend its energy along lines of least resistance—*i.e.*, into the atmosphere—whereas dynamite or other high explosives are so suddenly converted into gas that they have no time to do this, and their energy is consequently exerted equally all round. Place a huge block of steel on a bag of gunpowder in such a manner that the line of least resistance is through the ground, and gunpowder will seem to strike downwards.

Essentials of an Explosive.—The essentials, then, of an explosive are two—a combustible and an oxygen-carrier, and with few exceptions neither of these alone is an explosive. Thus coal-gas, petroleum, which includes ordinary paraffin oil, petrol, naphtha, benzoline, etc., and acetylene (uncompressed) are merely combustible, and no more explosive than charcoal or sulphur. In the same way saltpetre, one of the commonest oxygen-carriers, is not of itself explosive. This must not be taken to imply that no possible risk of explosion is to be anticipated from the presence of any of these substances. Coal-gas and acetylene have only to be mixed with air in proper proportion to become violently explosive, and the same may be said of petroleum vapour, which by some qualities of petroleum is rapidly given off at ordinary temperatures. Solid combustibles (see Chapter IV., p. 149) such as charcoal and sulphur, must, on the other hand, be reduced to very fine dust before they can lead to danger *of this sort* in the presence of air only, and even then this dust must be distributed in proper proportion

through the atmosphere before explosion can ensue, so that the risk from these two materials may, therefore, be regarded as remote. Of the oxygen-carriers, chlorate of potash is the only one of these commonly met with which parts with its oxygen so readily as to lead to an explosive risk. Fires and explosions have been caused on several occasions by this substance accidentally coming in contact with organic or other combustible matter, and a few simple and obvious precautions should therefore be observed by those who find it necessary to keep it in quantity.

Before explosives can be stored legally, it is necessary to obtain a licence from the Local Authority, and in order to get such licence, the Chief of Police of the district must be notified, and the necessary forms filled in.

The officer of the local authority has power to enter licensed premises and see that the legal precautions are taken, and that the trader does not keep more than the law allows.

For purposes of sale, the explosive or fireworks are best stored in a building or fireproof safe detached from a dwelling-house, and a safe distance from any public place or thoroughfare. In most cases, persons who wish to keep explosives erect a small brick building in a back yard or garden. When this mode of storage cannot be arranged the trader is allowed to keep a small quantity, usually one quarter that which would be allowed in a proper store, in a substantial receptacle inside his house or shop.

Even the quantities which are allowed to be kept for retail trade are sufficient to do a large amount of damage in the event of explosion, and therefore the importance of taking the most stringent precautions to prevent the explosive from being ignited cannot be over-estimated.

The receptacle in which explosives are kept must be exclusively appropriated to such use, and must be kept locked so as to prevent inexperienced persons from access to the explosive. The interior of the receptacle must be kept free from grit or exposed iron, and must be kept clean and free from spilt explosive.

It is of great importance that receptacles used for the storage of explosives should be kept within reach of a door, through which it can be removed altogether from the building in case of fire. The Chief Officer of the Fire Brigade in every town should keep himself informed, not only as to the premises which are registered for explosives, but also as to the position of the receptacle in each case.

The most frequent cause of explosion, and the one against which the most careful precautions must be taken, is the direct application of a spark or flame. The striking of a match in order to examine the contents of the receptacle is reckless folly. Small hand electric lamps and torches can now be purchased in every town, and should be the only illuminant used. It is advisable to cover the floor immediately round the receptacle with linoleum or other soft material, which will not only facilitate the sweeping up of any spilt explosive, but will also prevent the possible striking of a spark between a nail in the floor and one in the boot of a person approaching the receptacle.

The spontaneous ignition of an explosive is seldom the cause of an accident in small stores now that makers fully recognise the importance of the nitro-compounds being properly manufactured. Nevertheless, it is *not* advisable to keep old samples of such explosives, or samples the origin of which is at all doubtful.

Some of the worst accidents with explosives which have occurred in towns have originated in the filling of sporting cartridges in gunmakers' shops, but in every case some gross breach of regulations has led to the disaster. Almost every operation of manufacture carried on with explosives is attended with some degree of danger, and though the operation of filling cartridges is not regarded as one of the most dangerous, it is nevertheless one in which ignitions sometimes occur. Consequently, strict precautions should always be taken in the room where the operation is carried out. The most important of these is the limitation in the quantity of explosive present. No other work should be carried on at the same time, and no fire or artificial light of an unsafe kind should be in the room; it is also advisable to limit the number of persons in the room to two. The filling bench and the floor should be covered with linoleum, or similar material, in order to facilitate the sweeping up of spilt explosives.

Those fire brigade officers who act as inspectors of explosives should study the text-books to be obtained upon this subject, together with the details of construction of the places of storage, etc.

It is most important that the difference between "explosion risk" and a "fire risk" should be understood clearly. Highly inflammable articles must be kept at a safe distance from explosives. It would appear superfluous to mention this fact were it not that many accidents have occurred through the infringement of this rule. A case in which considerable damage was done by the explosion of a quantity of gunpowder, occurred in a building which was also used as a benzoline store, and was due to the accidental ignition of the benzoline.

From a fireman's point of view it may be stated that *gunpowder can safely be removed from* premises *on fire*, if the heat is below 500° F. (260° C.), provided always that the packets are intact and protected from sparks, etc., and as such temperature would render it impossible for men to work in its locality, it follows that removal can take place whenever the heat can be borne.

The destruction of explosives may well fall within the duty of a fire brigade officer, and it is well for him to know how best to dispose of dangerous goods that may have been seized by the Police or ordered to be destroyed.

Gunpowder may be dissolved in water, and, provided plenty of water is used to wash away the saltpetre, only carbon remains. If the saltpetre is not removed, and the water is allowed to evaporate, the residue will readily explode. Should plenty of space be available, the gunpowder may be laid out in a long line and fired from one end by a safety fuse. If more than one train is laid at a time, sufficient space must be allowed to prevent any risk of more than one line being ignited at a time. The same ground should never be used a second time until the heat of the first explosion is well out of the soil, and any second stock of gunpowder to be destroyed must be kept well out of the way.

Explosives composed of nitrate of ammonium may be spread over damp soil, when, being of a hygroscopic nature, they are soon rendered harmless. These nitrates when mixed with soil become good fertilisers.

Explosives used for blasting, such as dynamite, carbonite and the gelatines, should be removed from their wrappings and cases, and laid in lines upon open ground, if possible at an angle of say 45° to the direction

in which the wind is blowing. They should be well moistened with petroleum, and ignited at the windward end by a safety fuse. The same precautions should be taken as are given above for gunpowder.

Detonators are most difficult to dispose of, and the Home Office should be consulted in any case where they cannot be thrown into deep water at sea. Upon no account should they be cast into rivers or ponds. The only alternative is to destroy them in very small quantities at a time, in suitable locations well away from buildings. Too much care cannot be exercised.

CHAPTER VII.

INSURANCE.

Insurance or Assurance is an arrangement or system, by which it is sought to guard against the pecuniary consequences of certain so-called accidents to which we are liable. Some branches of insurance are aptly described as a "contract of indemnity."

In the early days of the mercantile marine a merchant of the time of Queen Elizabeth would stake his all in fitting out a ship and its cargo for foreign trade. After it left the home port only casual news would be received until its return, usually with a cargo of valuable products from the countries it had visited. The profits of a successful voyage were often enormous. Hence the saying "wait until my ship comes home." The loss of a ship was disastrous. In order to provide against a total loss mutual arrangements between merchants were made by which individual merchants took shares in the ship or cargo. This system gave way to that of capitalists undertaking for certain commissions to reimburse the merchants for any loss they might sustain, and to the formation of marine assurance societies, afterwards consolidated into legal companies.

There are few persons to whom the destruction of their dwellings or their household goods would not be a serious calamity. To meet such disasters there are traces, indeed, in earlier times of enforced or voluntary contributions towards the relief of sufferers by fire, but it was only at about the beginning of the seventeenth century that systematic provision was made. The great fire of London in 1666 first caused definite schemes to be suggested for the formation of underwriting by individuals or by clubs upon the lines common to the shipping industry. An attempt was made to engage the corporation of London in a public scheme of fire assurance; but in 1681 the first regular office for assuring against loss by fire was opened by a combination of persons "at the back-side of the Royal Exchange," and it was followed by others. Of the assurance offices that still survive, only one, the Hand-in-Hand, dates from the seventeenth century (1696), (absorbed in 1905 by the Commercial Union), it is said to have had fire engine and corps in 1699; followed by the Sun, 1710, Union 1714 (absorbed by the Commercial Union in 1907), Westminster 1717 (absorbed by the Alliance in 1906), London 1720, and the Royal Exchange 1720, while only three date from the second half of the eighteenth century, the Salop (absorbed by the Alliance in 1890), Phœnix 1782, and Norwich Union 1797. In Scotland the first fire office was established in 1720. In Germany the first proprietary office was opened in 1779. Benjamin Franklin was one of the directors of a fire office in Philadelphia in 1752. In France the first dates from 1816, and the first in Russia from 1827.

The London Fire Engine Establishment when started on the 1st of January, 1833, was supported by ten Fire Insurance Companies—viz.,

The Sun, Imperial, Westminster, Atlas, Alliance, London, Royal Exchange, Union—who remained until the Establishment was transferred to the Metropolitan Board of Works on 1st January, 1866, the Protector which joined the Phœnix in 1836, and the Globe joined the Liverpool and London in August, 1864. The following also joined and remained to the end:—Phœnix, 16th May, 1833; Guardian, 8th July, 1833; Hand-in-Hand, 15th July, 1934; Norwich Union, 1st January, 1835; Scottish Union, 1st January, 1836; Protestant Dissenters, since named General, 1st January, 1838; Church of England, 13th July, 1846; Liverpool and London, 1st January, 1848; County, 1st January, 1849; Royal, 24th June, 1849; Lancashire, 4th October, 1852; Northern, 1st January, 1854; Manchester, 1st April, 1854; West of England, 29th September, 1858; Scottish Provincial, 1st January, 1859; Queen, 8th May, 1861; Commercial Union, 4th November, 1861; North British and Mercantile, 3rd November, 1862; London and Lancashire, 19th January, 1863; and the London and Southwark, 14th November, 1864. Other companies joined, but left before 1st January, 1866, for the following reasons:—British, 10th November, 1835 to 1843, on joining the Sun; Licensed Victuallers, since named Monarch, 1st January, 1836, to 29th June, 1857, on joining the Liverpool and London; York and North of England, 1st October, 1836, to December, 1842, when it gave up business; Law, 1st January, 1846, to 1st January, 1860, was dissatisfied; Legal and Commercial, 1st April, 1850, to 1st January, 1855, on joining the Manchester; Equitable, 1st January, 1857, to 31st December, 1860, joined Unity; Unity, 30th June, 1857, to 31st December, 1842; Bank of London, 11th November, 1857, to 3rd December, 1858; Leeds and Yorkshire, 1st March, 1858, to August, 1864, these last three joined the Liverpool and London; The State, 8th February, 1860 to 1861, when it ceased.

In 1694, under William and Mary, a stamp duty of 6d. was imposed on all fire policies, doubled in 1698, and increased to 3s. 10d. per policy in 1713.

In 1782 fire assurance was made liable to an *annual duty* at the rate of 1s. 6d. per £100 insured. This duty was increased in 1797 to 2s. per cent., in 1805 to 2s. 6d. per cent., and in 1816 to 3s. per cent., at which rate it continued, and yielded some one and a half millions.

The duty was objected to as a discouragement to prudence, and as disproportionate to the rate of assurance to which it was added. It was partially remitted in 1864, and abolished in 1869, except for a stamp duty of one penny per policy, which has recently been increased to sixpence.

The sums assured by the British Fire Offices on which duty was paid were, in 1783, about £135,000,000; 1800, about £200,000,000; 1820, about £427,000,000; 1840, about £645,000,000; 1860, about £1,000,000,000; 1868, about £1,430,000,000.

What the sums assured amount to at the present time is difficult to estimate, as the growth of the business of fire assurance has been commensurate with the increase of wealth and commercial activity, and now in many cases "inclusive policies" are issued which cover, not only loss by fire, but through Explosions, Theft, Accidents to servants, Riot, Bursting Pipes, Rent, and many other risks. Policies covering standing charges and loss of profits as a consequence of fire are very popular with people in a large way of business.

In the administrative County of London alone the total amounts assured against fire have risen from £394,130,651 in 1866 to £2,018,618,825 in 1923.

Space will only allow each decade to be given from 1866 to 1898, after which date a rough estimate of the loss by fire in the County of London is added ; also see Fig. 103.

The rough estimate includes both assured and unassured property, but does not extend to expenses incurred by the Assurance Companies and others arising out of claims for damage resulting from fires, nor do they include any consequential losses which owners of property might have sustained.

Year.	Amount for which Property was Assured.	Estimated loss mentioned above.			
1866	£394,130,651	...			
1876	579,796,226	...			
1886	741,099,316	...			
1896	876,034,252	...			
1898	909,962,574	£569,445			
1899	932,598,661	464,228			
1900	963,291,097	515,349			
1901	975,014,285	656,854			
1902	991,201,032	812,040			
1903	1,010,397,295	400,874			
1904	1,023,041,470	394,425			
1905	1,032,092,845	449,191			
1906	1,040,057,846	521,056			
1907	1,055,200,172	493,389			
1908	1,072,640,212	446,853			
1909	1,083,274,627	699,329			
1910	1,094,946,216	602,100			
1911	1,115,375,519	737,221			
1912	1,132,491,717	421,909			
1913	1,140,948,050	339,080			
1914	1,152,838,453	538,374			
1915	1,182,310,862	997,214	including	£607,593	due to air raids.
1916	1,223,783,240	839,342	,,	£196,247	,,
1917	1,294,300,489	1,452,565	,,	£842,571	,,
1918	1,412,031,259	1,292,681	,,	£366,236	,,
1919	1,652,594,359	1,511,051			
1920	1,985,050,773	1,819,540			
1921	2,056,011,341	1,733,861			
1922	2,008,026,537	708,876			
1923	2,018,618,825	727,901			
1924	not ready.	911,997			

From the above it will be seen that there has been a fairly regular rise from the sum of £394,130,651 in 1866 to £2,056,011,341 in 1921. This enormous increase of nearly one and three-quarter *thousand millions* (£1,661,880,690) is in some measure due to the enhanced value of the stocks held by traders. The increase per cent. annually since 1917 has been—1918, 9·10 per cent.; 1919, 17·04 per cent.; 1920, 20·12 per cent.; 1921, 3·57 per cent., a decrease of 2·33 per cent. in 1922, but a further increase of ·53 per cent. in 1923—this is a total addition of over one-half the sum assured in 1917.

Fig. 103 is a graph of the estimated fire loss, 1898-1924.

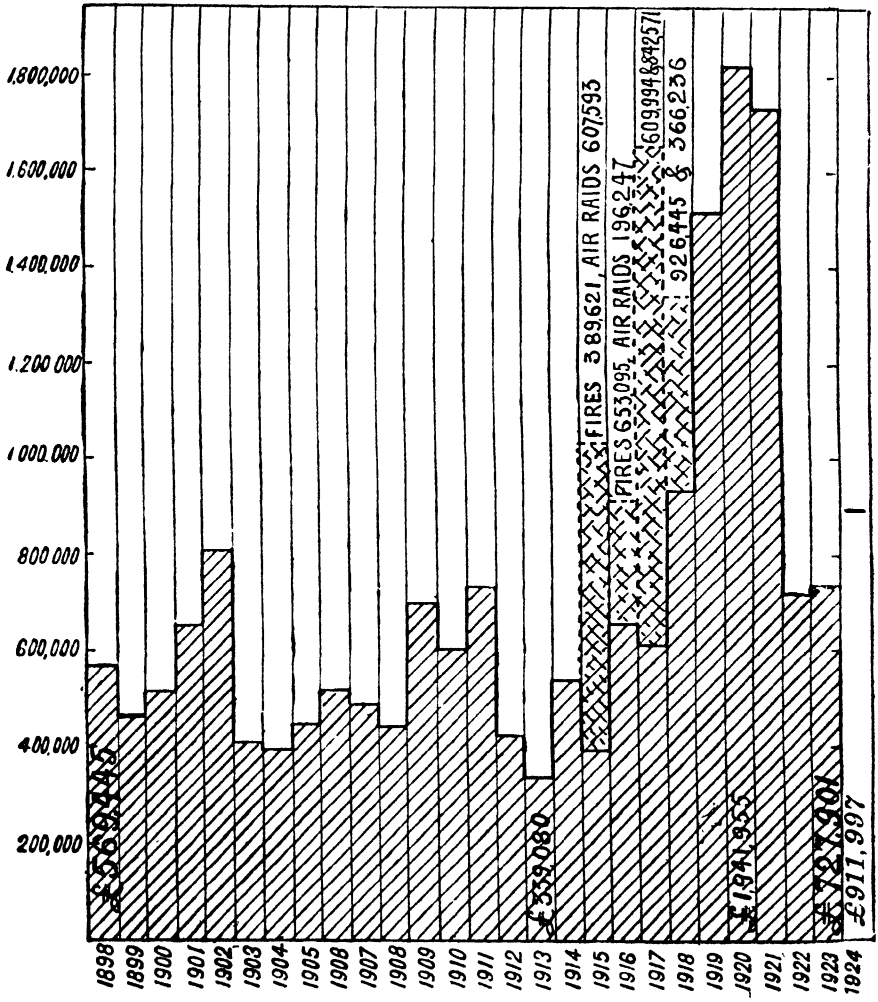


Fig. 103.—Rough estimate of the monetary loss caused by fire in the County of London during the years 1898 to 1923. These estimates do not extend to expenses incurred by insurance companies and others arising out of claims for damage resulting from fires, nor do they take account of any consequential losses which owners of property may sustain.

During the years 1915, 1916, 1917, and 1918 considerable loss was sustained due to air raids and explosions; these sums are shown super-imposed above the yearly loss.

It was estimated in 1913 that over £6,000,000,000 (six thousand million sterling) was the total amount insured in the United Kingdom against

fire, and assuming the average rate to be 3s. (three shillings) per cent., the premium income would amount to £9,000,000 (nine million sterling).

The *Times* newspaper each year estimates the fire loss in the United Kingdom in which the damage amounted to £1,000 or more. Twenty per cent. has been added for losses under £1,000.

	£1,000 or over.		Under £1,000.		Total.
1914, ...	£3,745,100	+	£749,020	=	£4,494,120
1915, ...	4,205,100	+	841,020	=	5,046,120
1916, ...	3,300,400	+	660,080	=	3,960,480
1917, ...	4,000,000	+	800,000	=	4,800,000
1918, ...	5,500,000	+	1,100,000	=	6,600,000
1919, ...	9,462,000	+	1,892,400	=	11,354,400
1920, ...	9,374,000	+	1,874,800	=	11,248,800
1921, ...	8,128,000	+	1,625,600	=	9,753,600
1922, ...	6,218,400	+	1,243,680	=	7,462,080
1923, ...	7,191,850	+	1,438,370	=	8,630,220
1924, ...	5,017,400	+	1,003,480	=	6,020,880

The *Times* now states that 50 per cent. should be added for the losses at fires under £1,000 damage, but as the average of 19 years in the London Estimate is under 20 per cent., this percentage seems fair. Consequential small losses of which the Brigade was not informed should not reach 30 per cent.

To a considerable extent the increased loss in recent years represents the increased values of buildings and other property assured, and doubtless the period of declining trade may have contributed. During the year 1920 fires in the United States and Canada (according to the New York *Journal of Commerce*) caused a fire damage of \$330,853,925 = £88,227,713, being, with the exception of 1906 (the year of the great disaster at San Francisco), the heaviest on record.

The Auditor-General's Report upon British Government trading from August, 1914, to March, 1919, states that the war risk premiums received exceeded the payments on account of losses by £10,917,245 for aircraft and £22,609,685 for marine assurance. Outstanding claims would reduce the sum, but the final outcome will show a large profit to the Government.

From the above it will be seen that fire insurance companies have long since passed out of the category of benevolent societies, and are now vast financial organisations, supporting an army of officials.

Agents for fire, life, accident, and marine insurance, etc., are to be found in nearly every position in society, many firms being agents for two or three companies. If to these be added the local advisory boards, the shareholders, the directors, of whom over 123 are Peers of the Realm, and about 42 are Members of Parliament, and others, it will be readily understood how the enormous vested interests of the companies are protected.

In 1909 The Assurance Companies Act (9 Edw. 7 Ch. 49) was passed, making it obligatory for every Assurance Company to deposit the sum of £20,000 with the Government before any new office could commence business, and a further sum of £20,000 in respect of each class of business in respect of which a separate assurance fund is required to be kept after the first.

The annual returns of fire insurance business published by the Government give a large amount of information. The summary in the return issued in 1924 for the year 1922, gives the incomings :—

For Unexpired Risks, . .	£22,518,515	= 23 %	of total incomings.
Additional Risks, . . .	21,029,650	= 21	,, ,,
Premiums, ...	55,002,053	= 55	,, ,,
Interest, ...	938,012	= 1	,, ,,
	£99,488,230		

And Outgoings :—

*	For Claims paid and outstanding,	£29,407,371	= 30 %	of total outgoings.
†	Commission, . . .	9,430,789	= 9	,, ,,
†	Expenses, . .	13,217,655	= 13	,, ,,
‡	Profit, . . .	1,910,439	= 2	,, ,,
*	Unexpired Risks, . .	22,596,027	= 23	,, ,,
‡	Additional, . . .	22,925,949	= 23	,, ,,
		£99,488,230		

* = 53 per cent. † = 22 per cent. ‡ = 25 per cent.

Of the premium income received in 1922, 53 per cent. was set aside for the payment of claims for fire losses, 41 per cent. in commission to agents and in expenses, and the balance in profit and additions to the reserve funds.

The General Reserve Funds are very large ; in 1919 they appear to have been over £10,000,000, and have been increased since, besides which the companies have considerable sums available in uncalled capital.

The interest from the invested funds and the profit allow most companies to pay their shareholders a good dividend upon the nominal amount of each share, together with a bonus at intervals.

Also, "The multiplication of insurance companies, and the number of agents employed in getting people to insure, substantially on the same terms, in one company rather than another, materially enhances the premiums which the public have to pay." *

Lloyd's.—Since the amending Act of 1911, the amount of *fire* assurance underwritten by the members of Lloyd's has vastly increased. Some assurers consider a Lloyd's undertaking more adaptable to new forms of business than the policies of the assurance companies.

Building Societies, which have their own fire loss funds, find that upon the class of property covered by their loans (for the most part small risks on buildings of residential property), a very small sum is sufficient to cover their losses, and that the monetary reserve grows yearly far beyond any liability they undertake.

The mutual (or local) plan for the insurance of dwellings can be carried on at a low cost where the individual risks are small, where the expensive technical classification is not considered necessary, and where ample protection against fraud is provided by the vigilance of the neighbours. It must be properly administered for the *sole* benefit of the insured.

The management of mutual societies has a tendency in course of time to be controlled by a few individuals, who have not the enthusiasm of the original promoters, and consider their duties only from a personal and pecuniary point of view.

In Austria-Hungary, Germany, Switzerland and Sweden, National and

* From "Peace and Industry," Viscount Milner.

Municipal insurance has developed to a great extent, and there is no reason why such should not apply to Great Britain.

The author's opinion is that the carcase of all buildings subject to and paying rates should be considered as being under the care of the local authorities, and should be restored or replaced by them *at once* after a fire, the cost of such restoration or replacement being borne out of the rates of the community. The effect of such procedure would be that every ratepayer would be profoundly interested in fire-prevention, and constantly active in giving the alarm, and by all means in his power endeavour to keep the loss small.

It would be to the interest of the inhabitants to report to the authorities dangers of fire that are out of view of the public.

Large hoardings round vacant ground frequently hide from passers-by large quantities of rubbish of a combustible and hazardous nature, that only require a lighted match thrown down to cause a considerable fire.

The annual value of rateable property can be divided between (*a*) the land, (*b*) the buildings. The total value of the buildings and the maximum sum the local authority might be called upon to pay in the case of a burnout might be fixed at twenty times the rateable value, less, of course, the salvage price of the stone or bricks, etc.

The owner could by arrangement with insurance companies or underwriters cover his liability for any larger amount that he thought well, as indeed most would, by insuring the contents, decoration, loss of the use of the premises and trade.

The local authority should have full power to restore at once the fabric without any interference by the owner or third parties, unless by agreement with the local authority the owner accepts a sum in lieu of his claim. Any dispute to be settled by the local Bench of two Justices, whose decision should be final.

The result would be that the local authority would by themselves or by contractors provide a stock of building materials and have the call upon workmen ready at all times to commence the re-instatement after a fire, and most houses would be rendered weather-proof and cleared up within a few hours. Energetic authorities would employ officials and firemen who would clean up and commence the repairs as part of their fire duty.

The saving to the general public would be enormous, both in inconvenience and cost.

It would require a very strong Government to pass any such law, considering the enormous personal interest in fire insurance companies, but in time it will be done.

Most local authorities have officials that could undertake the work, and in a very short time the effect upon the fire loss of the country would be substantial

The fire loss for 1912 has been given as—

*Canada, ...	12 shillings per head of population.
*United States, . . .	10 shillings and 7 pence per head of population.
England, ...	2 shillings and 3 pence per head of population.
Germany, ...	10 pence per head of population.

and most of the causes of fire are preventable.

* In the Northern part of the Continent of America wood is largely used in the construction of buildings.

In U.S. of America, where the fire loss per capita is far in excess of European countries, great endeavours are being made to instil into the minds of the public the huge loss they sustain, and to impress upon them the fact that they, and they (the public) alone, can reduce the waste.

The National Board of Fire Underwriters publish from time to time warnings.

Fig. 104 is from "Safeguarding America against Fire."

Mr. Edward Atkinson, of America, said, "The only persons who can prevent loss by fire are the owners or occupants of the premises; upon them rests the responsibility for heavy loss in nearly every fire."

The whole gist of the fire problem may be said to be comprised in the above few words, and it is in the power of the owners and occupiers to reduce the fire loss of the world to very small dimensions.

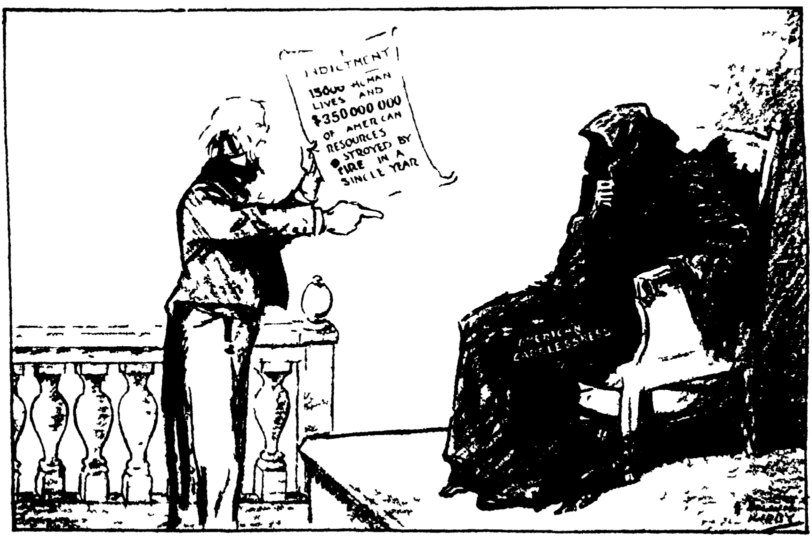


Fig. 104.

Views showing streets and buildings with such detail that individual houses and their surroundings can be distinctly seen can now be obtained by means of Aerial Photography.

In some large cities abroad prints of these photographs are being used by Insurance Companies to determine the risks from fire of blocks of buildings, with a view of fixing the rate of assurance. The size of the streets, and directness of the way from a fire station is also considered. It is proposed from time to time to repeat these photographs, and then the Insurance Companies will be able to ascertain if any alterations in the area appearing on the photograph have taken place. The premium would then be adjusted to meet the new conditions, and increased or reduced accordingly.

PART III.—MEANS OF SUPPRESSION. MATERIAL AND PERSONNEL.

CHAPTER VIII.

FIRE STATIONS, LAND AND FLOATING—FITTINGS—BELLS—LIGHTING.

FIRE STATIONS.

Consideration on the Subject of Site, Plan, and Design.—This matter is generally one of much difficulty. Even where the number of sites are eligible many points call for settlement before, by the process of elimination of the less favourable, the real site is chosen.

For the purpose of setting out the important points to be borne in mind, it will be convenient to classify the districts in which a station may be erected. These will be found to fall roughly into two large divisions, viz. :—

I. Rural.
II. Urban,

and the latter of these may be again divided into—

(*a*) Purely residential neighbourhoods.
(*b*) Manufacturing neighbourhoods.
(*c*) A mixture of both (*a*) and (*b*), including possibly docks and wharves.

The consideration which should enter into the choosing of a site are very much more important in urban than in rural.

In rural areas the risk of fire is principally one of domestic and farm buildings and, unless factories or workshops are erected, need not be considered hazardous.

On the other hand, the risk in urban areas is much more liable to alteration in importance on account of changes in the use of premises taking place quickly and almost unnoticed.

The size of the station should, of course, be proportional to the work expected of it, and if the district is likely to change in character, say from a residential or "dormitory" district to a manufacturing one, sufficient site should be taken to allow for any expansion of the station necessary to cope with the increase of work likely to be thrown upon it.

Great care should, therefore, be taken in selecting sites. Regard should be paid to the topography of the district. Sufficient area should be taken to admit of the station being well spaced and in a position where egress and ingress for appliances would not be retarded or made difficult on account of narrow frontage or narrow thoroughfare on which the site abuts.

It is advisable to choose a site more or less removed from thoroughfares frequently congested or choked with traffic, and in addition the approaches should be at least 40 feet (12·2 m.) wide. A situation near cross roads, or a square or circus into which several roads discharge, should not be overlooked. It is an advantage if the brigade are able to turn out and get away with the minimum disturbance to the general public. Several instances are known where stations are in cramped sites and difficult of access for vehicular traffic. The effect of this misjudgment can only be seen when it is too late.

A very good site is one near the bifurcation of a wide street, as it admits of an alternative means of exit for appliances.

Another point to be considered is that the site should not be in a hollow. It is far better for the appliances to run down hill to a call than uphill, for the rapid mobilisation of a brigade and its early arrival at a fire play a most important part in the attainment of real efficiency of a fire service. The object of starting on a decline is more apparent when horses are used for traction.

The roadway immediately in front of the appliance room should be fairly level, with a slightly downward gradient sufficient to ensure the appliance an easy start.

So much for the situation of a site. Now, as to its size—and here a few points should be borne in mind, for upon their satisfactory solution depends the ultimate expense of building and the running charges of the brigade.

First of all, it must be decided whether the station is for firemen living in or living out. Then the question of horse or power propelled appliances should be thrashed out. Taking the latter question first, for the sake of convenience, it must be remarked that the tendency of all up-to-date authorities is to instal power-propelled appliances. The initial outlay and upkeep are not greatly in excess of those for horse-drawn appliances. Horses are now difficult to obtain in an emergency. It is necessary in the case of motors to arrange for repair shops and stores of a higher technical standard than for horse-drawn appliances, and the space taken up is, if anything, less. Stations equipped with horse-drawn appliances must have stables and fodder stores in addition to the engine repair shops, and more space is, therefore, required. A good drill yard is essential in both cases.

So far as a comparison can be made of the utility and speed of the two systems, the difference in practice will be found to be about as two to one. Motors can on a clear road travel forty miles (64·4 km.) an hour, but for the purposes of calculation an average speed of not more than 25 to 30 miles (40 to 48 km.) should be taken. In practice this is found to be the best that can be obtained.

Horsed appliances, even where the animals are stalled in the appliance room, require a longer period for turning out. Their speed may be taken in good travelling at 12 miles (19·3 km.) per hour, but this speed can only be maintained for comparatively short runs.

Therefore, it will be seen that whereas in the case of motors more technical equipment is necessary, the space occupied is less than for horsed stations, and the areas which can be served are twice as great as for horsed stations. The advantages for utility are certainly on the side of motor or power-propelled appliances.

Turning now to the areas which can be served and the disposition of stations. The real difficulty here is as to what may be considered the correct basis to take. Some may desire to work out the number of stations on the basis of the number of persons to be protected. This problem has been touched upon in the transactions of the Institution of Municipal and County Engineers. In a paper read before that Institution in June, 1915, a scheme was advocated that the number of stations to be installed as an adequate protection from fire should vary with the population :—

(*a*) Those of approximately 100,000 population.
(*b*) Those of approximately 50,000 population.
(*c*) Those of 20,000 and under.

If (*a*) is a manufacturing district, it was suggested three stations should be provided, or if they were properly situated, two would be sufficient. For (*b*) unless the district is scattered, one station, and in (*c*) one only.

This principle applied to large towns would result in the addition of a large number of stations to those already built, and the protection would be more than should normally be required. A better method for arriving at a solution of this problem is undoubtedly that of the area to be covered, and even then there seems considerable difficulty in fixing the number to avoid an over-allotment of stations.

In a large town there ought to be sufficient appliances suitably housed in stations so placed that the brigade can arrive at any point within five minutes after a call has been received *at the fire station.* Assuming motors are able nominally to travel at an average rate of 25 to 30 miles (40 to 48 km.) an hour—*i.e.*, 1½ miles (2·4 km.) in three minutes—and allowing two minutes for the turn out, a distance of 1½ miles (2·4 km.) should be covered in the three remaining minutes. One station would protect an area enclosed in a circle 3 miles (4·8 km.) in diameter, or, say, 7 square miles. This is purely a theoretical basis, but may be taken as a general rule, neglecting, of course, any considerations of defective surface, railway embankments, rivers, and hilly roads, or other obstructions which may be met with.

In a densely populated area or where exceptional risks and danger exist, additional protection will be required, and stations must then, of course, be placed at closer intervals.

No really satisfactory principle can be decided by reference to any towns or systems existing at the present time, that will comply with all circumstances, because, owing to the extraordinary differences in shape and size of the districts to be compared, no reliable data can be found on which to base a hard and fast calculation. It has, however, been found after many years' experience that the above basis of calculation—*i.e.*, one station per 7 square miles (18·1 km.^{2}) of area is the maximum which can be served by motor appliances with any degree of first-rate efficiency, and to give a fair protection from a "life saving" point of view. Where exceptional risk of the warehouse class and dangerous trades exist, additional apparatus will be required to supplement the local stations in the case of serious fires, and this can be provided chiefly by reducing the size of the areas allotted to each station below the maximum recommended above.

The remaining question affecting the size of the station is involved in what is known as the living in and living out systems. Upon the settlement

of this depends whether the station should contain living quarters or not, and must be dealt with at this stage, as it seriously affects the cost of the station.

It is obvious that if the men are to live with their families in the station the cost of the building will be higher than if only dormitories are provided. In pre-war times this extra cost of an up-to-date station in London could be taken at £500 per suite.

The custom of having the whole staff housed upon the premises was economical when married men were satisfied with only two rooms and the use of a common wash-house, W.C., and bath. Now, however, the effect of advancement in education and the general rising in the conditions of life, family men feel the need of conditions which the living-in system can hardly be expected to afford without providing each man with a self-contained flat. This is expensive, and it may be taken that in new stations the living-out system would be the better system to adopt.

Appliance Room.—In order to house a 50-feet (15·2 m.) escape on its trolley, or a turntable ladder, ready to turn out, it is necessary that the appliance room should have a depth from front to back of at least 34 feet (10·4 m.). The width will depend upon the number of appliances kept available for immediate use. Each bay must have doors not less than 11 feet (3·4 m.) wide, and 11 feet 6 inches (3·5 m.) high in the clear, whilst if mechanical turntable ladders are employed the height should be 12 feet (3·7 m.).

Where it can be arranged, it is a distinct advantage to have similar doors at the rear, so that the appliances may be drawn in from the yard after drills or returning from a fire, without obstructing the public way. In horsed stations at least one of these rear openings would be required for the doors opening into the duty stalls for the first turn-out. The off-duty horses being accommodated in other parts of the stable, so that they can be harnessed and brought forward to the duty stalls immediately on the departure of the first machine.

Appliance-Room Ventilation.—Where the ceilings of the appliance-room are perforated for staircases, sliding poles and similar openings, it is absolutely necessary to provide inverted coamings round such openings. The coamings should be carried below the level of the top of the doors, so that the doors will at all times form a permanent means of ventilation to carry off effluvia from stables and motors, and prevent odours from penetrating into the living quarters.

Appliance rooms, and, in fact, all the public rooms, should be kept at a suitable temperature. The only way to ensure that the internal combustion engines upon the motors will start readily is to keep the room at a fairly even temperature and free from draughts.

The most satisfactory heating is by low-pressure water, the radiators should be so arranged that each one can be shut off without interfering with the others.

Sliding Poles.—Sliding poles are a necessity in all fire stations where men are housed above the ground floor. The pole space can be constructed to provide comparative safety for the men and their families, if divided into sections corresponding with the heights of the various storeys. The annexed sketch (Fig. 105) will show how this can be done.

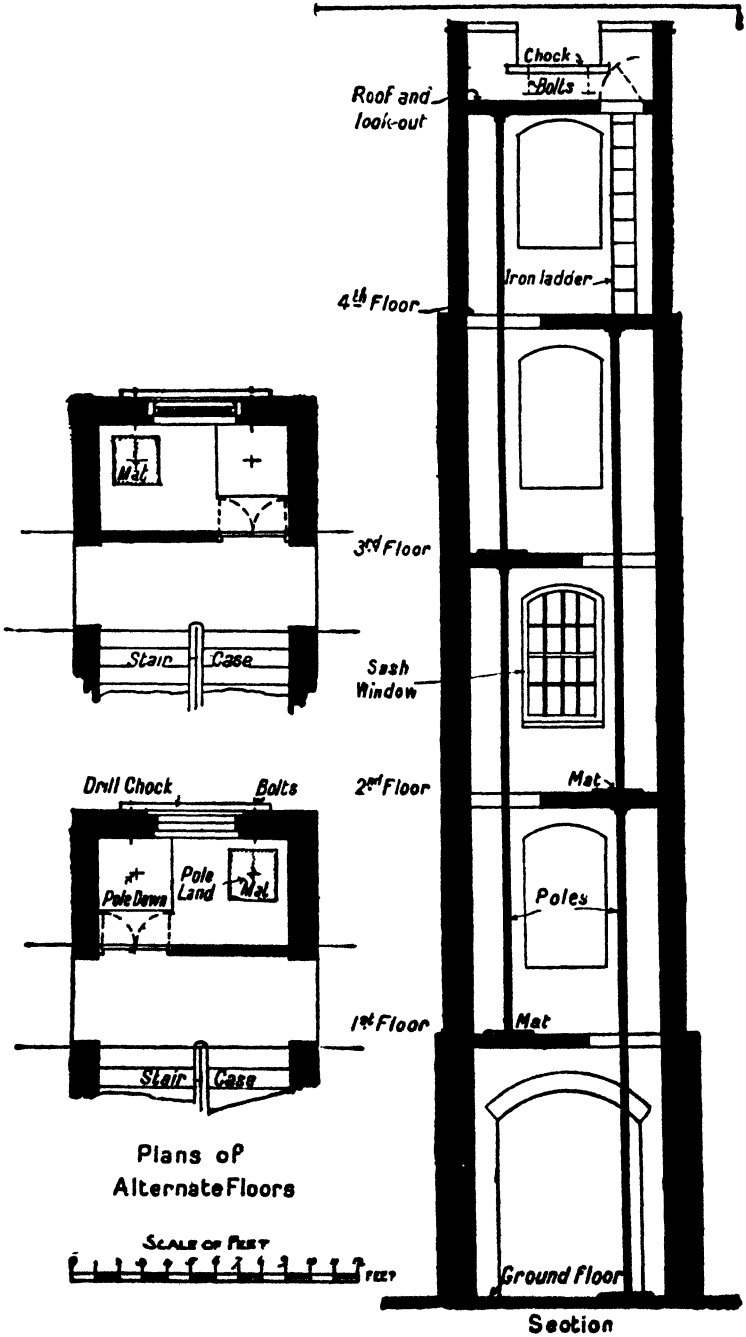

Chock
Bolts
Roof and look-out
Iron ladder
4th Floor
3rd Floor
Sash Window
2nd Floor
Mat
Poles
1st Floor
Mat
Ground Floor
Section
Mat
Stair Case
Drill Chock
Bolts
Pole Down
Pole Land
Mat
Stair Case
Plans of Alternate Floors
Scale of Feet
Feet

Fig. 105.

The openings in the floors through which the poles pass should be 3 feet (0·914 m.) square, and the pole to be in the centre of opening. The minimum width of pole house should be 6 feet (1·83 m.), and minimum depth 4 feet 6 inches (1·37 m.), to permit of a 1 foot 6-inch (0·46 m.) platform for door to open on and be clear of pole holes.

Poles should be of solid steel shafting 2½ inches (0·6 m.) in diameter, in single lengths, or of ⅜ inch (0·01 m.) thick polished tubing 3 inches (0·08 m.) in diameter. Brass-cased tubes can be used for smartness, but the jointing sometimes works loose and becomes dangerous. Poles should be caulked at flanges to prevent rattling. If a hollow pole is jointed in its length the connector should be at least 18 inches (0·46 m.) long. Jointed poles are better fixed at top and kept ½ inch (0·013 m.) short of floor, and bedded on a wad of felt. This puts the pole in tension when in use and prevents it bending. This mode of fixing is imperative if a pole is abnormally long and goes through more than two floors. Poles more than three floors long

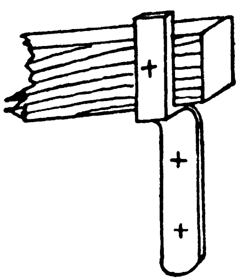


Fig. 106.—Teak Bearer for Hook-ladder Drill.—Fixed just above the window sills and securely bolted through the wall, but clear of it to prevent holding water.

Fig. 107.

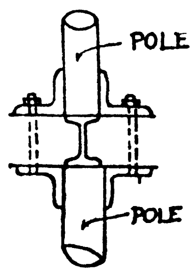


Fig. 108.

are not advisable—*i.e.*, two floors above landing floor—and then with the only entrance at the top.

The foot of each pole should be provided with a removable coir mat (Fig. 107) 2 inches (0·05 m.) thick, and not less than 2 feet (0·61 m.) across, either square or circular in shape. The top and bottom flanges of superimposed poles may be bolted together over the supporting rolled-steel joist (Fig. 108).

The above practically means one continuous pole from the ground to the floor level of the highest storey, and a second pole from the first floor level to the ceiling of the topmost storey. Doors folding inwards are required at each floor, fitted with door checks that can be regulated to close automatically and noiselessly and yet with sufficient force to secure the floor. The fastening arrangement should be above the top of the door within reach of an ordinary-sized man.

Doors to the pole space should be self-closing double doors, without rebates or meeting styles. The upper panels glazed in clear glass fitted with auto-spring latches fixed at the doorhead to be out of reach of children. Plates to warn people of the danger of entering may also be fixed to doors.

The doors should open upon the upper section of the descending pole to the next storey, and alternately storey by storey to the ground level (see Fig. 105). This system obviates any chance of two men jumping on to the pole at the same time.

A pole from a billiard room or mess room may have spring floor flaps operated by foot pressure on a spring button. They should have a protecting railing. Double hand-rails to the stairs are most useful in buildings that are not fitted with poles.

The outside of a sliding pole space may also be used for hook-ladder drill. An ordinary sash window about 3 feet (0·914 m.) wide and 6 feet (1·83 m.) high is suitable, but a teak bearer or chock should be securely bolted in front to avoid damage to sill by the serrations on the ladder hook. This chock must be securely bolted through the wall and be fixed clear of sill for drainage purposes, or it can be dropped into forged brackets as per sketch (Fig. 106). Bracket and bolt are arranged so that the chock can be turned over when worn.

Cantilever brackets may be put upon the outer walls (clear of drill windows) to dry hose in fine weather.

Poles can be combined with staircases, and if wide enough the centre well of stairs used as the pole house or for hose-drying.

The staircase can be carried up an extra flight and the top formed as a flat and used as a look-out with compass board and speaking tube or tele phone to watch room.

The ladder drill can then be continued to the flat, and a heavy malleable-iron cleat (Fig. 109) bolted through the flat for " lowering " drill.

Watch-room.—The watch-room or duty-room should be placed so that men on duty can have constant supervision of all persons entering the station and at the same time a full view of the whole of the appliance room. The size of this room will depend as to whether fire alarms and telephones are located therein. It is a much better arrangement for the alarms and telephones to be in a separate secluded chamber especially adapted for the purpose and entirely removed from outside interference, and thus keep the attention of the attendants centred on their work, and also secure the privacy of the room.

An office for the officer in charge with the usual furniture should be conveniently situated to afford him the means of general supervision of the work of the station at the same time being as much removed as possible from the public gaze.

In every case of a living-in station a private entry from the street should be provided in order that the members of the firemen's families, particularly the children, shall have no excuse for wandering about the business part of the premises.

The private coal stores and common wash-house and hot and drying closet, if any, should be near the quarters and distinct from the station proper. Each wash-house should have a W.C. at hand for the exclusive use of the women.

The provision of an efficient ambulance service throughout the country is, and will be, more in demand. Much has been done in the last few years to provide such a service. The Firemen as a class are with their training eminently fitted to undertake this work, and if all take their turn the ambul-

ance duty will be found an agreeable relaxation from the monotonous waiting for fires. Provision should, therefore, be made for ambulances. The number of ambulance calls far exceeds those to fires.

If a small room for reading can be provided, it is a great assistance to men wishing to study. In practice there is a tendency to use any extra room provided for this purpose as a store for the station office. This should not be allowed.

It is better that linoleum, oil cloth, and similar floor covering are not washed, but rubbed daily with a rubber upon which a very small quantity of wax is spread. (See recipes in Appendix.)

The floors of all outside W.Cs. and Lavatories should have a fall of half an inch to the foot towards the door, so that any overflow may be at once seen.

Hose.—As is mentioned in the chapter on hose, the efficiency of a fire brigade much depends upon the care of the appliances, especially the hose.

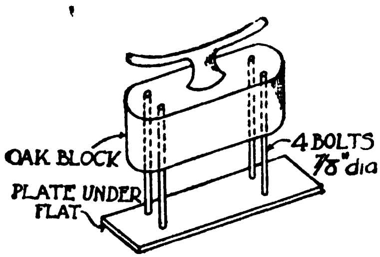


Fig. 109.

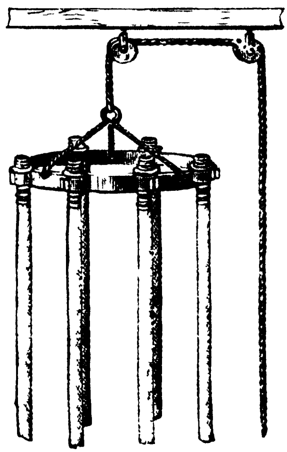


Fig. 110.

Therefore a fire station, however small, should have provided means for cleaning and drying hose, not only after fires, but at other times, to prevent rot through damp. Every advantage should be taken to expose hose to the sun's rays, and at small stations without high walls a pole slightly more in height than half the length of the hose will serve the purpose if fitted at the top with a ring upon which are pulley blocks for hauling up the hose. The top should have protection from rain in the shape of a small roof or umbrella (see Figs. 110 and 111), and should the pole be of wood, chocks will be required to allow men to reach the top to reave the ropes and attend to the blocks. If an iron railway signal post is used, foothold can be found in the lattice.

Canvas hose must be kept clean, and in order to prevent an undue quantity of water being used when washing it, a trough sufficiently long to take the hose used (*i.e.*, half the full length) should be provided. The trough may be of concrete 2 feet (0·61 m.) wide by 9 inches (0·23 m.) deep, with a fall from one end to the other; at the upper end a good sized tap or

hydrant should be fixed and a plug at the lower end. A perforated pipe is sometimes used along the top side of the trough. When the trough is in a building it can be covered by a 1-inch ledged flap in suitable lengths, hung to fold back against the wall. (See Fig. 112).

At stations that would not justify the expense of a concrete trough, half round 18-inch (0·46 m.) stoneware drain-pipes let into the ground will answer the purpose. They should be laid with proper fall, with tap at the upper

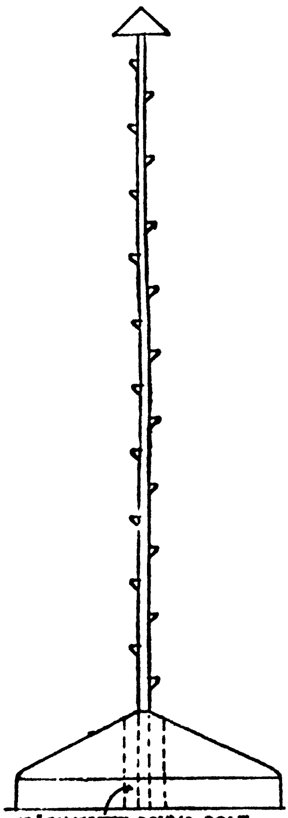


Fig. 111.

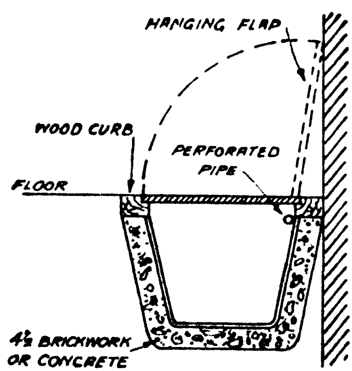


Fig. 112.

end, and a 3-inch drain-pipe at the lower end; a wooden plug will be found sufficient to hold up the water.

If even the above cannot be had, two halves of a paraffin barrel placed some feet apart with board resting upon the edge of each will answer the purpose.

The tubs should be half filled with lukewarm water, a length of dirty hose placed in one, then draw out one end of the length on to the board, brush it well with soap and water each side and the edges, pass the cleaned

part into the second tub and continue until the whole length is cleaned, then carry clear of the ground to a place where it can drain and dry.

All hose should be washed at least once a year.

Quarters, etc.—The following rooms are common to both kinds of stations:—Recreation room of sufficient size to take a full-sized billiard table, and also space for smaller tables for writing or games.

A recreation room which should also have attached to it a lavatory. A hot closet for drying the men's clothes should be provided, independent of the wash-house.

A favourite means of planning living quarters was to arrange the whole of the rooms facing a street over the appliance room, with a corridor some 4½ feet (1·4 m.) to 5 feet (1·5 m.) wide, common to all rooms, with the w.c., bathrooms, placed on the rear side. The object of a corridor of this width was to allow plenty of space for the occupants to place their furniture therein, and yet leave sufficient room for the passage of traffic whilst the rooms were undergoing the periodical cleaning and renovation. When the construction of artisans' dwellings became general, and in deference to the opinion of the Medical Officers of Health, much attention was given to planning, and through ventilation was insisted upon, and further, in order that each suite of apartments should be self-contained, it was necessary to provide additional conveniences inside the outer doors of each suite. These outer doors usually abutted upon open landings in order to obtain the necessary ventilation.

The minimum size of the different apartments provided in London is upon the lines of the best class of artisan dwellings, and is given under A, and the sizes suggested under the Government, 1919, housing schemes under B. The minimum floor space being in feet super between skirting and excluding chimney breasts, etc., is—

	A	B
Living room, . . .	160 (14·86 m.^{2})	183 (17·0 m.^{2})
One bedroom, . .	120 (11·15 m.^{2})	183 (17·0 m.^{2})
One bedroom, . .	110 (10·22 m.^{2})	135 (12·54 m.^{2})
Scullery, . . .	50 (4·66 m.^{2})	70 (6·5 m.^{2})

together with W.C. and bathroom.

The sufficiency of these areas depends, however, materially upon the plannings of buildings, and the relative positions of the doors, windows, fireplaces, etc. It is possible for a room of 120 super feet (11·15 m.^{2}) to be rendered incapable of providing convenient space for two beds by reason of bad planning.

It must also be remembered that as it may be necessary at some time or other to remove coffins and such lengthy objects from bedrooms, provision must be made that will permit such removal without any inconvenience, and as easily as possible.

Living out Station.—As before mentioned a station planned for the living-out system does not require so large a building as the living-in system, but provision must be made for proper dormitories, etc.

Suppose that the duties will be worked 48 hours "on" and 24 hours "off"—in other words, that the men will be clear of the station every third day, and as two-thirds of the strength on duty will be practically confined

to the station during their two days duty, arrangements should be made to ensure that they may have every chance of making themselves comfortable.

As the work of contented men will be found of higher value than that of discontented men, opportunity should not be lost in making them as happy as possible.

Each man should have allotted to him for his exclusive use a bedstead and a good size locker. There are several ways in which this accommodation can be provided.

Iron bedsteads may be adopted, in rows with lockers near the heads. This may be improved upon by having curtains hung on iron rods between beds, but undoubtedly a better system is to give each man an enclosed cubical not less than 10 feet (3 m.) by 6 feet (1·8 m.) with separate door and window. The doors opening into a corridor 4 feet (1·2 m.) wide, leading directly to the head of a sliding pole. In this case it would be unnecessary to provide a locker as a good sized lock-up box that can be kept under the bed would answer the purpose. The beds being hinged on the side can be fastened up against the partition when not required. A small folding table should also be provided and each cubicle supplied with a light. It will therefore be found that an area of 84 feet (7·8 m.^{2}) per man inclusive of corridor is required.

The mess room, kitchen, and larder should be of sufficient size to accommodate two-thirds of the men at one time. Gas will be found the most convenient fuel for the cooking and heating. It will also be necessary to provide a small wet and dry canteen.

N.B.—The superficial space allowed per fireman in dormitories in foreign towns is—

Hamburg, ...	45½ feet (4·23 m.^{2}).
Berlin, ...	43½ ,, (4·0 m.^{2}).
Ghent, ...	81 ,, (7·5 m.^{2}).
Boston, U.S.A., ...	41 ,, (3·81 m.^{2}).

Adjacent to each dormitory should be arranged the necessary lavatories and baths. Ordinary slipper baths are the most appreciated, but a spray bath with hot and cold water will allow a larger number of men to wash down in a minimum of time. Recesses 3 feet square (0·9 m.) with a curtain in front enable a number of men to dress at the same time and make the very best use of the shower bath.*

Floating Stations.—No work on fire stations would be complete without some reference to floating appliances used for fire fighting. It is impossible to dogmatise upon a subject of this nature, as the conditions vary so much. To determine the number of floating fire appliances necessary in any set of circumstances cannot be stated according to any scheme of distribution either on the basis of area to be covered or population to be protected. This question must be settled, not only according to the risk involved and fires likely to be encountered, but it must bear a direct relation to the character or topography of the district. These vary from a shallow river

* Sinks and lavatory basins should be not less than 42 inches (1 m.) from the floor, otherwise they are apt to be used for extraneous purposes.

Separate dormitories and a small combined mess and sitting-room should be provided for the officers.

or canal to a deep water bay of considerable extent, and from a port of immense wharves and docks with an enormous amount of destructible wealth to others of a mere harbourage. Obviously the question is difficult, but there are strong arguments to prove the value of floating appliances to cope with fires on shipping in port and the property on shore adjacent to wharves and docks.

When the number and distribution has been settled according to the best evidence which can be obtained, next comes the question of design, and here it will be found that there is a direct advantage in having a fire float of deep draught, as it is more manœuvrable and offers a better resistance to the back pressure caused by the jets. But there are many types of floats for fire-fighting purposes. Some are merely land appliances run on to rafts. The earliest in London were of this design. These are useful in shallow water provided they can be towed about conveniently and that the engine can be shipped and unshipped whenever required, with the minimum of delay. This involves many difficulties which are not apparent at first examination, and leads one to the conclusion that as so much depends upon the co-operation and easy working of other things, and so many opportunities occur for a serious breakdown in management, that it is better to have the tug and appliance for pumping together in one compact arrangement.

Sometimes the vessel is at work in such a position that it cannot be moored, and again, it is necessary for them to travel long distances. Also specially designed construction is necessary to overcome shallow draught difficulties.

At sea-going ports employing a number of tugs, most of which will always be under steam, it is a good plan to have many of them fitted with a fire pump and to allot a cabin for the exclusive purpose of storing hose and other fire appliances, these appliances should be under the charge of the chief officer of the fire brigade, and a fireman should be sent to inspect them weekly.

Upon the alarm of fire being given the tugs should make for certain stations to pick up some firemen and receive orders.

The advantage of such a system is that a number of vessels fully equipped with steam up are always available, the size of the pumps will be governed by the risks with which they have to deal.

Telephones, Bells, etc.—For use during night-time electric lights automatically switched on should be provided throughout the station. In each man's bedroom a large lamp should be so placed that the man leaving the door open gets sufficient illumination to enable him to reach the general lighted portion of the station in 17 seconds. It is also necessary that call bells should be fixed in the stores, basements, and other out-of-the-way places, in order that the men when working in different parts of the premises should duly receive the call. The bells to the men's quarters should be able to be rung both individually and collectively. Where the quarters are some distance from the duty room it is a great convenience if a telephone is placed handy for the common use of men living near. Where the distances are short, communication may be carried out by a speaking tube.

The station must be connected with the public telephone service, with one or more lines, and in towns having several exchanges a line should run to each. As far as possible the number 100 should be allotted for the fire

to the station during their two days duty, arrangements should be made to ensure that they may have every chance of making themselves comfortable.

As the work of contented men will be found of higher value than that of discontented men, opportunity should not be lost in making them as happy as possible.

Each man should have allotted to him for his exclusive use a bedstead and a good size locker. There are several ways in which this accommodation can be provided.

Iron bedsteads may be adopted, in rows with lockers near the heads. This may be improved upon by having curtains hung on iron rods between beds, but undoubtedly a better system is to give each man an enclosed cubical not less than 10 feet (3 m.) by 6 feet (1·8 m.) with separate door and window. The doors opening into a corridor 4 feet (1·2 m.) wide, leading directly to the head of a sliding pole. In this case it would be unnecessary to provide a locker as a good sized lock-up box that can be kept under the bed would answer the purpose. The beds being hinged on the side can be fastened up against the partition when not required. A small folding table should also be provided and each cubicle supplied with a light. It will therefore be found that an area of 84 feet (7·8 m.^{2}) per man inclusive of corridor is required.

The mess room, kitchen, and larder should be of sufficient size to accommodate two-thirds of the men at one time. Gas will be found the most convenient fuel for the cooking and heating. It will also be necessary to provide a small wet and dry canteen.

N.B.—The superficial space allowed per fireman in dormitories in foreign towns is—

Hamburg, ...	45½ feet	(4·23 m.^{2}).
Berlin, ...	43½ ,,	(4·0 m.^{2}).
Ghent, ...	81 ,,	(7·5 m.^{2}).
Boston, U.S.A., ...	41 ,,	(3·81 m.^{2}).

Adjacent to each dormitory should be arranged the necessary lavatories and baths. Ordinary slipper baths are the most appreciated, but a spray bath with hot and cold water will allow a larger number of men to wash down in a minimum of time. Recesses 3 feet square (0·9 m.) with a curtain in front enable a number of men to dress at the same time and make the very best use of the shower bath.*

Floating Stations.—No work on fire stations would be complete without some reference to floating appliances used for fire fighting. It is impossible to dogmatise upon a subject of this nature, as the conditions vary so much. To determine the number of floating fire appliances necessary in any set of circumstances cannot be stated according to any scheme of distribution either on the basis of area to be covered or population to be protected. This question must be settled, not only according to the risk involved and fires likely to be encountered, but it must bear a direct relation to the character or topography of the district. These vary from a shallow river

* Sinks and lavatory basins should be not less than 42 inches (1 m.) from the floor, otherwise they are apt to be used for extraneous purposes.

Separate dormitories and a small combined mess and sitting-room should be provided for the officers.

or canal to a deep water bay of considerable extent, and from a port of immense wharves and docks with an enormous amount of destructible wealth to others of a mere harbourage. Obviously the question is difficult, but there are strong arguments to prove the value of floating appliances to cope with fires on shipping in port and the property on shore adjacent to wharves and docks.

When the number and distribution has been settled according to the best evidence which can be obtained, next comes the question of design, and here it will be found that there is a direct advantage in having a fire float of deep draught, as it is more manœuvrable and offers a better resistance to the back pressure caused by the jets. But there are many types of floats for fire-fighting purposes. Some are merely land appliances run on to rafts. The earliest in London were of this design. These are useful in shallow water provided they can be towed about conveniently and that the engine can be shipped and unshipped whenever required, with the minimum of delay. This involves many difficulties which are not apparent at first examination, and leads one to the conclusion that as so much depends upon the co-operation and easy working of other things, and so many opportunities occur for a serious breakdown in management, that it is better to have the tug and appliance for pumping together in one compact arrangement.

Sometimes the vessel is at work in such a position that it cannot be moored, and again, it is necessary for them to travel long distances. Also specially designed construction is necessary to overcome shallow draught difficulties.

At sea-going ports employing a number of tugs, most of which will always be under steam, it is a good plan to have many of them fitted with a fire pump and to allot a cabin for the exclusive purpose of storing hose and other fire appliances, these appliances should be under the charge of the chief officer of the fire brigade, and a fireman should be sent to inspect them weekly.

Upon the alarm of fire being given the tugs should make for certain stations to pick up some firemen and receive orders.

The advantage of such a system is that a number of vessels fully equipped with steam up are always available, the size of the pumps will be governed by the risks with which they have to deal.

Telephones, Bells, etc.—For use during night-time electric lights automatically switched on should be provided throughout the station. In each man's bedroom a large lamp should be so placed that the man leaving the door open gets sufficient illumination to enable him to reach the general lighted portion of the station in 17 seconds. It is also necessary that call bells should be fixed in the stores, basements, and other out-of-the-way places, in order that the men when working in different parts of the premises should duly receive the call. The bells to the men's quarters should be able to be rung both individually and collectively. Where the quarters are some distance from the duty room it is a great convenience if a telephone is placed handy for the common use of men living near. Where the distances are short, communication may be carried out by a speaking tube.

The station must be connected with the public telephone service, with one or more lines, and in towns having several exchanges a line should run to each. As far as possible the number 100 should be allotted for the fire

service, to enable subscribers to readily send through calls to fires. Where the brigade has more than one station a private line connecting each station with the central one should be provided. The quarters and office of the

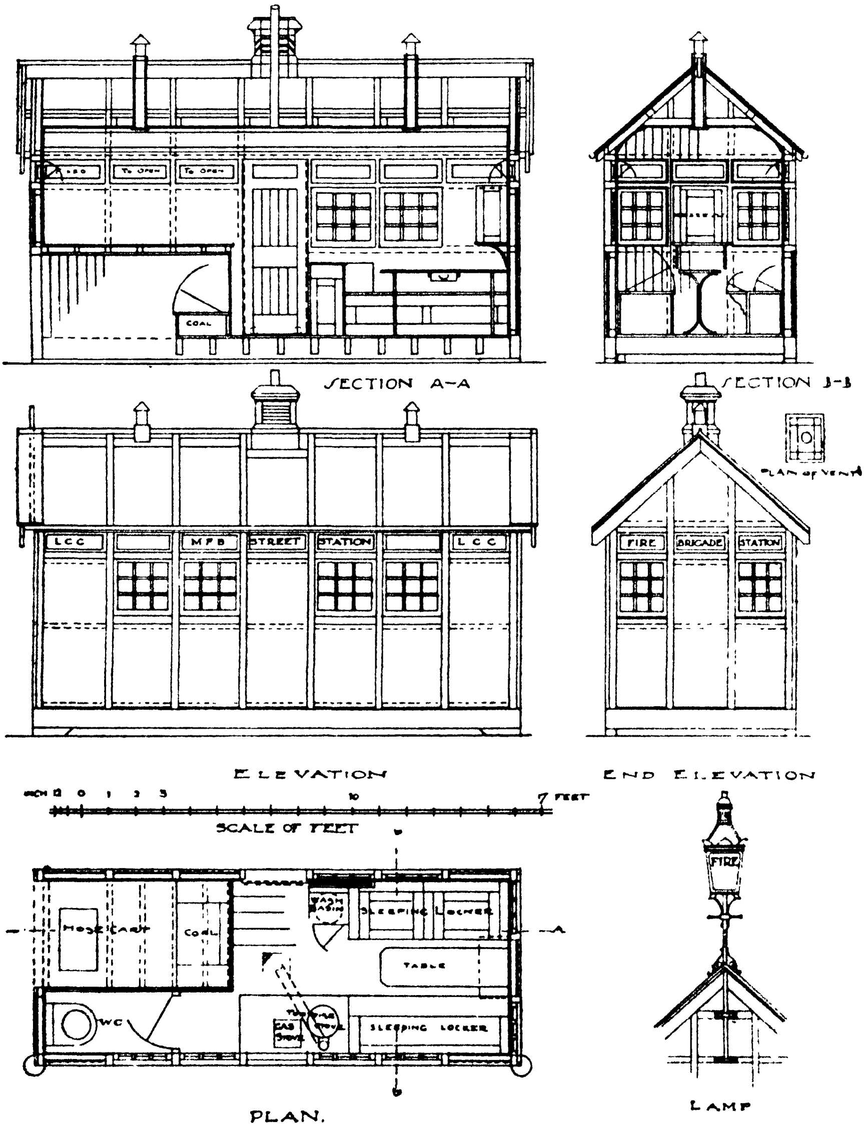


Fig. 113.—A Street Station.

officer in charge should also be connected by telephone with the duty-room, and by means of a plug connected to the public service when necessary.

Lighting.—Where it is obtainable, electricity is undoubtedly the best

lighting medium for use in fire stations, and if care is taken the cost should not be excessive. A dual system of wiring should be installed.

(*a*) On the general lighting of the station which normally would be alight from sunset to midnight, after which pilot lights only would be required.

(*b*) A second system of emergency or call lights, whereby lights sufficient for the illumination of the station can be switched on from the watch-room at the same time as the call bells are actuated.

These call lights to be switched off immediately the appliances have left the station; in order to remind the man on duty, a red light should be fixed in the duty-room to show when the call lights are on.

A sufficient number of oil lamps should always be kept trimmed and ready for lighting in case of emergency.

In order to obviate undue excitement, shouting or other noise, where more than one appliance is manned at a station, it is a considerable advantage to institute a system of coloured lights to designate the appliances required, and thus warn the men told off for duty with that machine.

If the area to be protected is all within 1½ miles (2·4 km.) of a motor-equipped station on lines set (see p. 225), it would be unnecessary to institute "out duties," in Street Stations, unless for very exceptional purposes. Drawings of one are given (Fig. 113) should the necessity arise for one to be established. All out duties of this nature should be in telephonic communication with the central station.

CHAPTER IX.

NOTIFICATION OF FIRES—TELEPHONES—FIRE ALARMS—SPRINKLERS.

NOTIFICATION OF FIRE.

THE old custom of having watchmen on towers to give alarm in case of fire was abandoned as electrical science progressed, and the adaptability of electricity to the special needs of the fire brigade service encouraged electrical engineers to apply their energies to this unique branch of their work, with the result that at the present time several excellent systems are available.

The importance of electricity as a time-saver in announcing the existence and location of a fire, and thereby giving the firemen prompt notice, is more appreciated in the United States of America than in England; it is self-evident that the more promptly a fire can be attacked by the firemen, the more easily it can be extinguished—and with the minimum of loss.

The following descriptions are largely taken from a very excellent paper read by Mr. J. Sinnott, in November, 1909, at a meeting of the Institution of Post Office Engineers. This paper has been as far as possible brought up to date. The original was considered of such value that it was published as an official technical instruction on fire alarm systems.

Fire Alarm Systems.—The first application of the Electric Telegraph to the transmission of Fire Alarms was made in Berlin in 1849. This was followed in 1853 by the installation in that city of a system of street alarms devised by Messrs. Siemens, of Berlin. The alarm boxes were connected in series in a closed metallic circuit, terminating at the Chief Fire Station, where the battery was placed. Each street post had an automatic telegraph transmitter which, when started by the person giving the alarm, interrupted the permanent current a certain number of times, so transmitting a signal in Morse code to the fire station, where it was recorded on a paper tape by an auto-starting Morse register. A distinctive set of Morse signals was allocated to each street post to indicate the locality of the alarm received. This sytem proved of such great utility that, in the course of a few years, similar fire telegraphs were installed in other German cities, and it was also adopted in Amsterdam and Stockholm. Although the results of experience and the general progress in electrical science have led to much development of Messrs. Siemen's system, the original general principles have been retained—namely, "*closed*" *metallic circuits for the Street Alarm boxes*, and a record in Morse Code of all alarms transmitted. The Morse code system of signalling was undoubtedly of great advantage, as it enabled the street alarms to be used by the fire department for the transmission of telegraphic messages in connection with its work. In this respect the introduction of the telephone has altered matters in recent years, and nearly all German Street Fire Alarms

of the present day are fitted with telephone apparatus, in addition to the automatic fire telegraph transmitter. As a consequence, Messrs. Siemens have recently devised alarm boxes with mechanism to signal numbers in place of Morse code. Each alarm box of an installation is distinctively numbered; the numbers representing the localities of the boxes.

These numerical signals, which are sounded three times on one or more gongs at the fire station and also recorded three times on paper tape there, are considered to be more easily determined than Morse code signals. Numeral signals possess the further advantage that the locality of the alarm given can be displayed visually throughout the fire department by means of plain figures.

The United States of America followed closely, but independently, the course taken by Germany in the matter of Fire Alarm Telegraphs, and this is what might be expected, because, on account of the dryness and high summer temperature which characterise the climate, fire risks are very serious; fire protection, or fire fighting as Americans term it, being, in the early part of the nineteenth century, regarded as a very important branch of municipal work.

America has, in fact, been conspicuously in the forefront in both fire alarm and fire brigade work. Previous to the introduction in 1850 of the Fire Alarm Electric Telegraph, New York was divided into eight fire districts. in each district a powerful bell was provided in a tower where a watchman was continuously on duty. Each tower commanded a clear view of its district, and it was the business of the watchman to look out for fires, and when discovered, to tap with a hammer on his tower-bell the number of his district. The other watchman repeated the taps on their bells, in this way spreading the alarm over the whole city. The first application of the electric telegraph was to signal the existence of fires from police stations and engine houses to the watchman.

Boston (Mass.) was the first city in the United States to adopt a street Fire Telegraph. It was designed by Dr. Channing and Professor Farmer, and was installed in 1852. The original plant comprised 19 bell strikers and 26 street signal stations. The alarm boxes depended for their operation upon the turning six times by hand of a crank which had a break circuit wheel fastened directly to its shaft. One-half of this wheel was so toothed that, in revolving, it transmitted signals which were recorded by a tape register and which represented the number of the fire district where the alarm was given; the other half of the wheel transmitted a certain number of current pulsations, recording on the register at the Central Station the number of the particular box operated. The Central Station then transmitted the alarm to the watch tower in the district concerned, where a local alarm to the firemen was given by means of the tower-bell. To ascertain the locality of the alarm a fireman had to go to a street box and count the taps of the small bell inside, these taps being sent from the Central Office when the alarm had been transmitted to the watch-towers. If a fireman on reaching the street box did not find the bell tapping, he signalled the Central Office and the operator there repeated the number. Notwithstanding the obvious imperfections of this system, reference to it is of importance, as it was the origin of the *numerical signal system*, the characteristic feature of American fire alarm telegraphy of to-day.

In 1859 Mr. J. Gamewell took over the Channing and Farmer patents and subsequently formed a company, the parent of the present Gamewell Fire Alarm Telegraph Company, for the purpose of improving and developing the fire alarm system. The work of this company has been so extensive that for a long time past the word "Gamewell" in the United States has been a synonym for "Fire Telegraph." It may be mentioned that quite 90 per cent. of the fire alarm telegraph systems in North America are of this company's production. A description of their modern apparatus and of the principles of their system will be given later.

It will be observed that signal boxes are almost exclusively used for the street alarms, and that there are but a few of the Annunciator kind. Signal boxes are those which transmit a definite code of signals when operated; annunciator those which merely "close" the alarm circuit, dropping an annunciator at the fire station to indicate the alarm effected.

It is, perhaps, unfortunate that similar statistical information is not available as to the fire alarm systems in other countries, especially in Great Britain; but it may be stated that the majority of systems in this country are either of the annunciator kind, merely consisting of the dropping of an indicator at the fire station, or more primitive still, of volunteer firemen's bells set in action by an electric bell-push or pull contact fixed outside the fire station. The number of street fire alarm systems in use in Great Britain is small as compared with the number in the United States, and are mostly of the signalling type, but new installations are now in progress of completion.

The history of the fire alarm telegraph in this country is largely that of London Fire Brigade systems, and as the experience of the various systems successively tried is not generally known, it will be of interest to state briefly what has been done. In the year 1877, Mr. Treuenfeld read to the Society of Telegraph Engineers a most valuable and comprehensive paper on the subject of Fire Telegraphs. He described the Continental systems, and advocated not so much the introduction of a particular system as the adoption of street alarms generally as a most useful aid in the "prevention" of serious fires. His statistics in this paper, and also in another on the subject read in 1888, amply prove the utility of street alarms. In these days there is no need to adduce further reasons, as the value of fire alarm telegraphs is fully admitted by every municipality that has installed them.

Until the late date of 1880, there was no system of street fire alarms in London, or in fact in any other town in Great Britain. The system first tried in London was that of the Exchange Telegraph Company. It was fashioned after the fire alarms then in vogue in America. The Exchange Company's system is shown in Fig. 114. "Closed" metallic circuits were used with the fire alarm boxes in "series." The alarm transmitter consisted of a short train of wheels regulated by an escapement. The main-spring of the train was wound-up by pulling a knob after the door was opened or the glass broken. Geared in this train was an ivory code signalling wheel W, the teeth of which differed in each transmitter. This wheel in rotating interrupted the line current a certain number of times, according to the number and arrangement of the teeth on its periphery. These interruptions or signals, through the medium of the station relay R, were recorded on the Morse embosser M, and were tapped out by the single stroke bell K. The

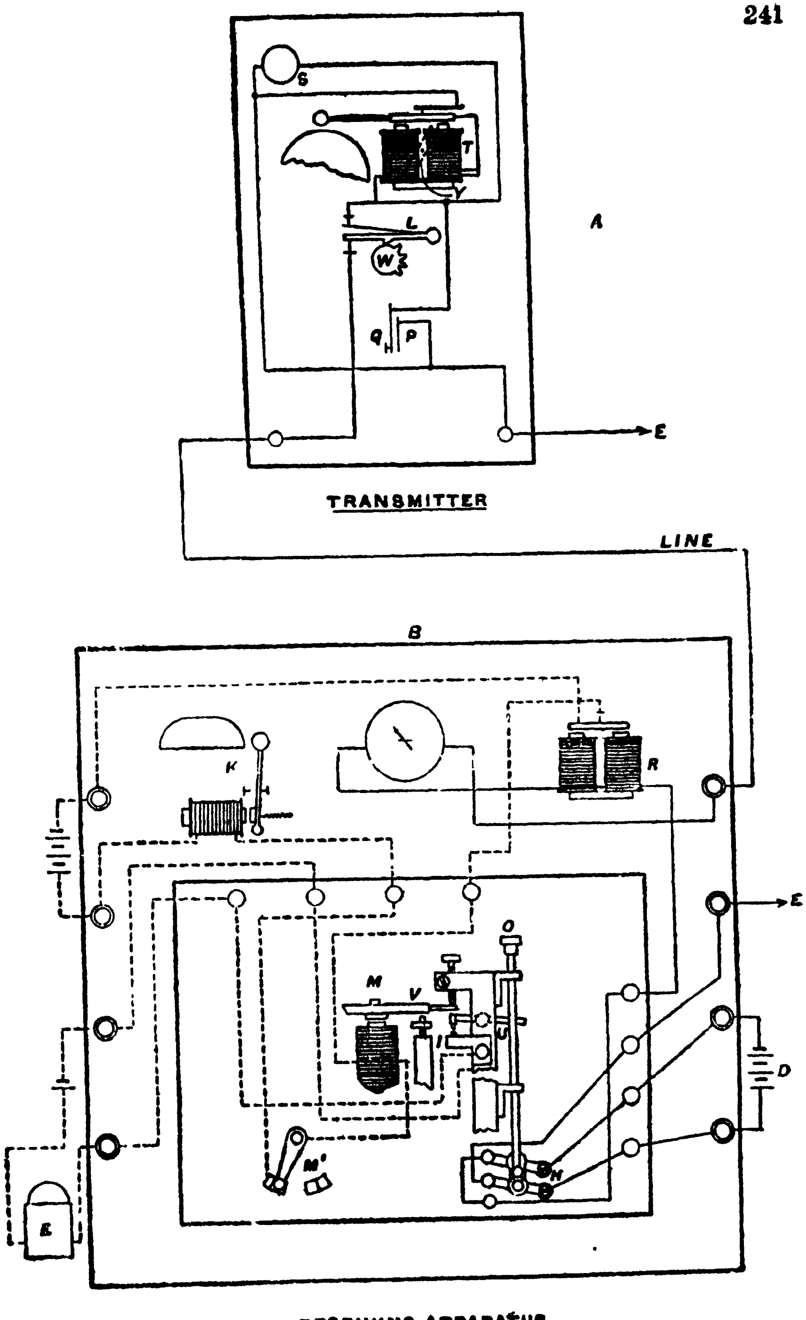

S
T
Y
A
L
W
Q
H
P
E
TRANSMITTER
LINE
B
K
R
E
O
M
V
U
I
M'
H
D
E
RECEIVING APPARATUS

Fig. 114.

Morse embosser on starting closed the local circuit of an alarm bell, E. The transmittor gave three repetitions of the signals before stopping. When the signals had been received on the Morse embosser the duty-man depressed the plunger switch, O, which broke the circuit of the alarm bell and reversed the line battery. The reversal of current acted on the needle, Y, at the transmitting alarm box, bringing a disc in position before an aperture and exposing the words, "Signal received"; at the same time an audible acknowledgment was given by a bell in the alarm box. As long as the door of the alarm box was closed or the glass remained intact, the springs P and Q were kept in contact, short-circuiting the box.

One hundred of the Exchange Company's fire alarm boxes, distributed over fourteen of the London fire station areas, were installed.

Almost simultaneously with the Exchange Company's system, one devised by Mr. E. Bright, Civil Engineer, was fitted up in connection with some of the other London fire stations. The number of alarm boxes of this type was one hundred and sixty, covering twenty-three station areas. Bright's system was based on the application of the differential balance method of locating faults devised by him. The line circuit with the alarm boxed in series was taken through one coil of a differential galvanometer which also acted as a relay, and was balanced by a compensation circuit connected to the other coil of the galvanometer.

Normally the fire alarm boxes were short-circuited. When the handle of an alarm was pulled, it removed the short-circuit on an electro-magnet inside the box. The resistance of the coils of this electro-magnet upset the line balance at the fire station and caused the galvanometer needle to deflect and ring the station alarm bell. To stop the ring, the duty-man turned a dial resistance in the compensation circuit until the galvanometer needle became neutral; the pointer on the dial resistance then indicated the locality of the alarm box pulled, as the resistance of the electro-magnet in each box differed from that of the others connected in series with it.

The duty-man, by means of a key in the line circuit, caused a pendulum attached to the electro-magnet in the alarm box to vibrate; and the movement of a disc attached thereto was intended to inform the caller that the alarm had been received.

In 1884 two London fire stations were fitted with a "series" circuit system devised by Mr. Spagnolletti, Engineer to the Great Western Railway; twelve alarm boxes were installed. The system had for a station receiver a step by step visual recorder, almost similar to the modern Train Describer. The alarm box contained a step by step transmitter made of two strips of metal connected together by insulating pieces like a ladder, the strips representing the stiles, and the insulating pieces the rungs. One stile was insulated at various points. A metal ball lying across the stiles connected electrically one stile to the other. The ladder was pivoted so that it tilted when the alarm handle was pulled, the lower portions being caught and retained by a pawl attached to the armature of an electro-magnet in series with the line circuit. The ball ran down the stiles and alternately broke and made the circuit, the pulsations of current actuated the station recorder, step by step and according to their number the pointer stopped on the dial at the name of the locality of the alarm box; the duty-man then pressed a switch restoring the station indicator to zero, and also increasing momentarily

the line current. This increased line current released the pawl and allowed the ladder to return by gravity to the normal position, resetting the ball and closing the circuit. This system gave so much trouble that its use was not extended.

A series circuit system devised by Mr. A. C. Brown was tried at Great Portland Street station, five alarm boxes being fixed in connection therewith. Each alarm box apparatus contained a pendulum contact breaker with a distinctive rate of vibration when set in motion. When an alarm was pulled its pendulum was set in motion, interrupting the current periodically, and affecting at the fire station an electro-magnetic indicator with a pendulum armature arranged to respond to the particular rate of current impulse. The station equipment included a series of pendulum indicators, each of which was regulated to correspond with a pendulum at one of the alarm boxes. The vibration of the pendulum armature indicated the alarm box, pulled and closed the local circuit of the fire bell common to each pendulum receiver. The pendulum transmitter and receiver were similar to the Pendulum Selector Telephone Call Apparatus described by Preece and Stubbs in their work on Telephony.

From various obvious causes these "series" circuit systems gave so much trouble that in 1886 the London Fire Brigade authorities decided to discard them altogether and to substitute the "open" circuit system with a separate wire to each box. Mr. A. C. Brown invented the system adopted, a single wire with earth return being used for each circuit. The alarm box apparatus was of a simple character. The handle of the alarm when pulled closed the line circuit through a retaining relay, a small bell of the short-circuiting type being in series. Closing the circuit dropped an indicator at the Fire Station and actuated a short-circuiting type of bell, common to all indicators on the alarm receiver board. The bell in the alarm box rang until the duty-man depressed a plunger-switch, cutting off the battery and releasing the armature of the retaining relay at the alarm box. The cessation of the ring given by the bell of the alarm box was intended to intimate that the call had been received. The system is shown in Fig. 115, except that it had not then got the telephone apparatus shown, this being added about 1898 (see Fig. 115*a*).

Two "open" circuit Alarm Systems designed by Messrs. Stuart and Moore were also tried by the London Fire Brigade. The alarm box in the first system of Messrs. Stuart and Moore was arranged so that when the handle was pulled it closed the line circuit. The handle was retained in the pulled-out position by the armature of an electro-magnet in circuit with the line. At the fire station a drop indicator and fire bell were actuated. The duty-man then by means of a switch increased the line current and caused the electro-magnet in the alarm box to attract the armature and release the handle. A hammer attached to this armature struck one blow on a gong; this was the reply signal.

Another system of Messrs. Stuart and Moore was of the pendulum type, and was tried at two fire stations. The alarm transmitter consisted of a pendulum which was set in motion by pulling the handle. The pendulum in motion intermittently earthed the circuit, causing a relay at the fire station to ring a fire bell intermittently.

The object of the regular intermittent rings was to distinguish genuine

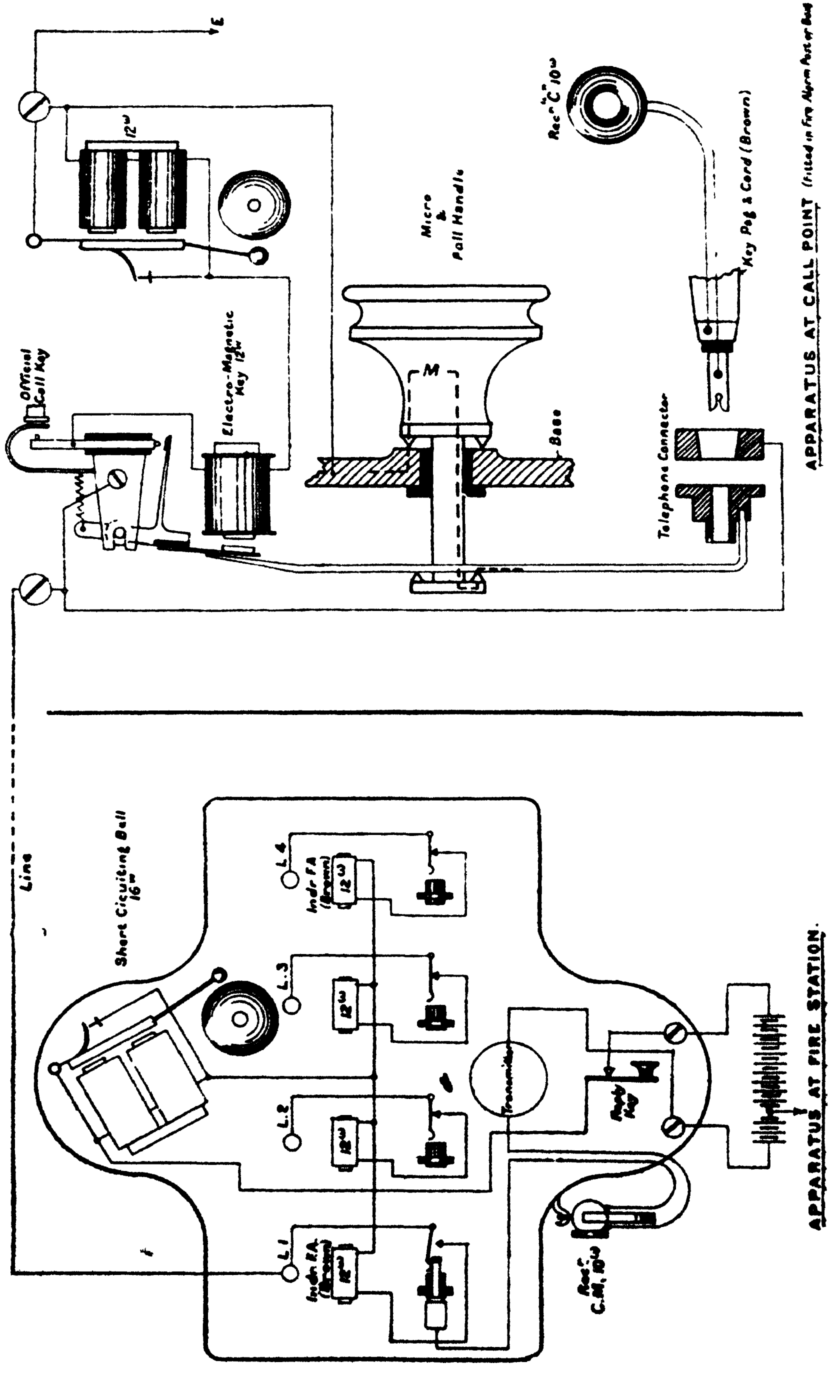

APPARATUS AT CALL POINT
Official Call Key
Electro-Magnetic Key 12w
Micro & Fall Handle
Base
Telephone Connector
Key Peg & Cord (Brown)
Line
Short Circuiting Bell 16w
Transmitter
Reply Key
APPARATUS AT FIRE STATION.

Fig. 115.

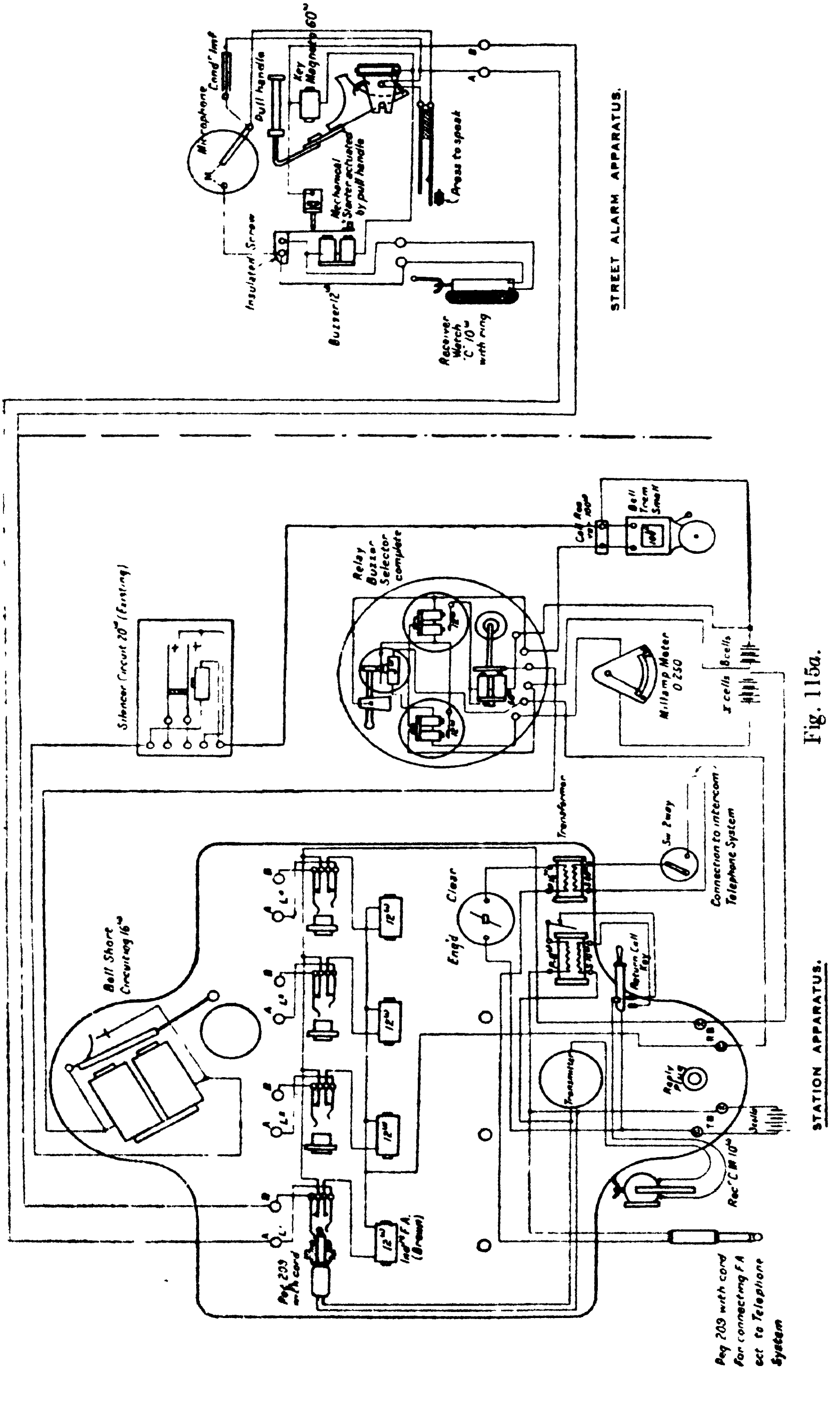

STREET ALARM APPARATUS.
Microphone
Pull handle
Key
Magnet
Press to speak
Insulated Screw
Buzzer 12
Receiver Watch 'C' 10 with ring
Silencer Circuit 20 (Existing)
Relay Buzzer Selector complete
Millamp Meter 0 250
Bell Short Circuiting 16
Clear
Eng'd
Transformer
Connection to intercom. Telephone System
Return Call Key
Transmitter
Reply Plug
Peg 203 with cord
Peg 203 with cord for connecting F.A. cct to Telephone System
STATION APPARATUS.

Fig. 115a.

calls from false rings brought about by earth faults. An indicator was provided for earth circuit. When the duty-man answered the call by pressing a switch, the line current was increased to an extent sufficient to actuate a single stroke bell in the alarm box, the beats corresponding to the vibrations of the pendulum, and in this way giving the reply signal or acknowledgment.

Messrs. Stuart and Moore's alarms were eventually abandoned in favour of Mr. A. C. Brown's apparatus; the London Fire Brigade authorities having decided to have only one style of alarm apparatus for all their fire stations; but the pendulum system is maintained by the Post Office at Newport (Mon.) and Lewes, Sussex. The principle of operations is as described above.

Mr. A. C. Brown's system, which, in common with the previous London systems, was installed and maintained by the Post Office, is still in exclusive use by the London Fire Brigade. Until recently it was subject to the defect of not providing any dependable means in the fire station for distinguishing false signals, due to electrical faults, from genuine calls caused by the operation of the alarm boxes. As this defect came increasingly into prominence with the extension of the system, it will be of interest at this stage to give certain particulars of the experience in this connection of the London Fire Brigade.

In 1888 the Chief Officer, Captain Sir E. M. Shaw, reported that during the preceding year 2,365 fire calls had been received by the fire brigade; of these, 1,195 were given by means of the fire alarm posts, but of this number 362 were false, and were set down to the following causes:—170 were malicious; 91 due to lines out of order; 13 to men working on wires; 14 to collisions of vehicles with the street fire alarm posts; 74 were not definitely traceable, but probably the majority were due to undetected electrical faults. Captain Shaw, whilst acknowledging the valuable services rendered by the street fire alarms, considered that the false alarm trouble was the most serious drawback to the extension of the system.

During the period 1900-1904, false alarms were unfortunately very frequent, owing to the fact that the provision of the Post Office Telephone Exchange system, then in active progress, necessitated considerable overhauling of the wire-routes, mostly underground, on which the fire-alarm circuits were carried. In recent years, although there has been a marked improvement in the maintenance of the wires, the number of false alarms continues large, as will be seen from Fig. 115*b*.

It must be borne in mind that an enormous mileage of wire is involved, and that an earth fault of only a few seconds' duration is sufficient to cause a false alarm. In fact, it is doubtful whether, with the fire alarm system just described, it would be possible to reduce the trouble very materially even if routes specially reserved for the fire alarm wires were provided. The cost of such routes would be so great as to restrict the extension of the street alarm system, which would be more disadvantageous to the community than the present fire alarm trouble is to the fire brigade. For this reason an attempt was made to overcome the trouble, and it was hoped that this would be done without appreciably diminishing the efficiency of the fire alarm, which it need scarcely be said is the most important factor in determining the value of any system. The London Fire Brigade accordingly

decided to try at Islington Fire Station a modification of the Fire Alarms on a plan similar to one then in use at Newcastle-on-Tyne.

The Islington trial was commenced in 1907. At first it was attended with such good results that the London County Council ordered in 1913 the remainder of their fire alarms to be altered on the lines of the modified system of Mr. A. C. Brown, as shown in Fig. 115.

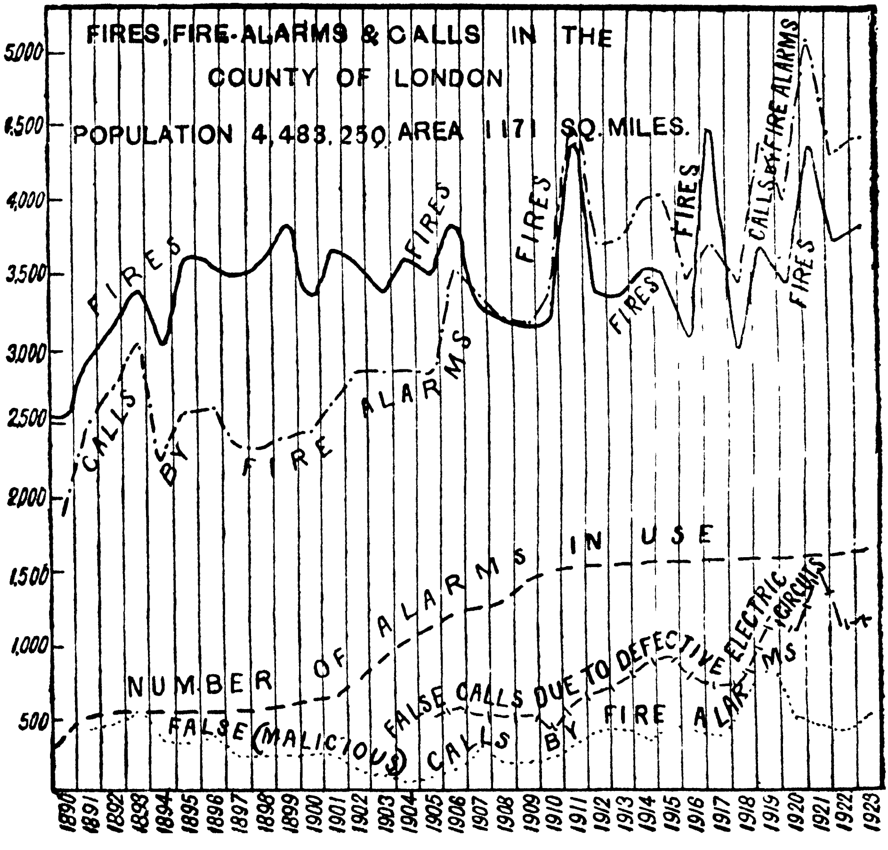


Fig. 115*b*.

Referring to Fig. 115, it will be observed that the bell in the alarm box has been replaced by a vibrator, or buzzer, as it is usually termed. The handle of an alarm, when pulled, trips the reed of the buzzer, starting it in vibration; this vibration is then maintained by an electro-magnet, through which the line circuit is closed in shunt with the retaining relay. The main battery current passes through a milliammeter, a combination of relays termed a "Relay Buzzer Selector," and through an indicator; there is a separate indicator for each circuit. The "Relay Buzzer Selector"

separates, as it were, the rapid vibratory current pulsations set up by the transmitting reed from the steady line current. The vibratory component actuates a special form of relay which controls the ringing of the fire bell, and also operates a slow action relay which is referred to on the diagram as a "Circuit Silencer." The armature lever of the slow action relay is attached to an air dashpot to retard the return of the lever when the controlling electro-magnet is de-energised. This relay closes the local circuit of the local alarm bells in the fire station for about twenty seconds. If a leakage of current takes place owing to a line insulation fault the buzzer selector "steady current" relay is actuated, causing the fault bell to ring and draw attention to the fault. This fault bell is also used for telephone calls made by the fire brigade from the street alarm posts. The operation of the Relay Buzzer Selector may be described briefly as depending upon the successive pulsations of current setting up minute but continuous vibration of a lightly balanced lever, one end of which rests on the diaphragm of a relay made like a telephone receiver. The fire bell relay is short-circuited by the contact between the diaphragm and the lever. The effect of the vibratory motion of the lever is to increase the resistance of this contact sufficiently to admit current to the fire bell relay. The latter relay closes the local circuit of the fire bell through a slow action relay, the object of which is to prevent a momentary impulse starting the local alarm slow action relay.

Practically at the moment a street fire alarm is pulled the fire station bells start to ring, and if desired the emergency lights can be switched on automatically as well. The return call key (see Fig. 115) is provided in order that the duty-man at the station may call the attention of a fireman if in the vicinity of a fire alarm post; the calling signal is produced from the telephone receiver, which is caused to set up a loud buzzing sound by means of the vibratory current applied to the line when the return call key is pressed.

The transformer on the fire alarm switchboard is used when it is required to speak from a street alarm post to a fire station other than the one to which the street alarm is ordinarily connected. It connects the street alarm circuit with the telephone intercommunicating switching system, which is in use between the headquarters' fire station and the superintendent's stations, and between the latter and the various out-stations of the brigade.

Trouble arose in several cases where the alarm had been pulled for a fire, by the small fault bell alone ringing, and not the large alarm bell, with the result that it was arranged that every ring should be taken as a call, but a reduced attendance of appliances when only the small bell rang. As the number of calls due to electrical faults continued to increase, orders were given in November, 1917, to discontinue the work of fitting the additions to this type of apparatus, and the London County Council paid £740 to the Post Office as compensation for the cost of the new fittings not used.

The percentage of false calls due to electric faults received from the street alarm posts in London is a serious matter (see Fig. 115*b*).

The question of false alarms, and particularly those due to defective electrical circuits, should be enquired into most seriously by the authorities. A percentage of faults of anything like twenty of the total alarms received should be capable of considerable reduction, and would justify a large capital outlay for improvement. One can hardly help feeling that bad workmanship

or inattention upon the part of the linesman is responsible for many of these defects.

Systems almost similar in character have been installed by the Post Office for the Corporations of Belfast and Newcastle-on-Tyne. In the Newcastle-on-Tyne system, although the buzzer type of alarm is employed, a buzzer relay selector is not used as a receiver; the buzzing signals are rendered audible at the fire station by means of a specially constructed telephone receiver fitted under the alarm bell. This bell can be temporarily stopped by pressing the short-circuiting button if it is required to render the " hooty " sound of the receiver more audible. At Belfast the system is practically similar to the old London one, with the exception that, instead of fixing the local reply bell in the street alarm box itself, it is fitted outside close to the top of the lamp standard carrying the street alarm, the object being to call the attention of the police with a view to the arrest of persons pulling the alarms without proper cause.

At both places the alarm circuits are wholly metallic, and on that account are not liable to get out of order through earth faults to the line wires as in the case of the London system. Of the simple forms of Fire Alarm Systems which have been installed by the Post Office in small towns, it will suffice to describe that known as type G. It is an open circuit system. When the alarm handle is pulled, the line is earthed through a shunted trembler bell; the handle in the pulled-out system is locked by a latch, which cannot be released until the fire brigade arrives and unlocks the alarm door. Closing the circuit in this way draws current from the central battery at the fire station through a non-polarised drop indicator provided with a local battery circuit to which the firemen's bells are connected. These bells are fixed in the men's houses, one circuit usually serving several bells. At the fire station the bell circuits are bunched together and connected through to the common local circuit of the drop indicators on the switchboard. An " electro-magnet indicator key " is provided for each alarm box circuit in order that the ringing of the bells may be stopped until the street alarm can be reset, during this period the indicator affected shows a white star. When the box is reset and the circuit is thereby broken, the indicator key restores the normal condition of the circuit, the white star indication disappearing. A telephone jack is connected across the indicator of each circuit so that a telephone receiver may be plugged in to detect the pulsations of the local trembler bell in the alarm box, and in this way confirm that the call is due to the alarm box having been actuated.

Reverting to the subject of the " closed " circuit alarm systems, upon which principle fire alarm practice outside this country is almost exclusively based, it might be thought that the experience of the London Fire Brigade is condemnatory; but on reviewing that experience it appears possible that if the work and apparatus generally had been up to present-day standards, the conclusions would have been reversed.

German and American authorities are of opinion that the " closed " metallic circuit principle should alone be employed, in view of the nature of the conditions to be met in fire alarm telegraphy. The street fire alarm differs essentially from other telegraphic signalling systems in that it is very infrequently used. Even when tested daily there is no certainty with an " open " circuit arrangement that the alarms may be in order at the moment

when required to transmit a fire call, as disconnections of line wires and battery leads cannot be made to give dependable automatic notification of their occurrence; and in connection with matters of such vital importance as the transmission of fire alarms, automatic safety and control devices to provide against these contingencies are generally considered indispensable. Although a "closed" circuit system possesses the great advantage that such devices can be readily applied, its application to circuits with one call point each would be costly. It is, therefore, the practice with "closed" circuit systems to connect in series in each circuit as many call points as a reasonably safe length of line will admit. This in itself is a very desirable feature. It reduces to a minimum the cost of the external wiring of a system, especially where metallic circuits are desired; and it may be stated as a general principle, that whether a system is of the "open" or of the "closed" circuit type, it is advisable that it should be completely metallic and not employ earth return. Earth return means, not only that the signals may be closely if not exactly imitated in certain circumstances by line insulation faults, but also that the circuits may be more often out of order, the insulating material of wires being mechanically the weakest portion of every electrical system. Reference was made at the outset to the "closed" circuit series system of Messrs. Siemens; and although several other such systems are in existence, further reference will be limited to a description of that of the Gamewell Company, which is so widely in use in America, and which in recent years has been installed in several of the large towns in this country.

Gamewell System.—It is stated that one of the first objects of Mr. Gamewell's invention was to provide for adequate protection of the mechanism of the street fire alarm box against the extreme weather conditions of the United States. This he accomplished in a simple but effective way, by mounting the signal mechanism in a metallic case insulated from and enclosed in an outer metallic case.

In the company's modern boxes, which now contain more intricate mechanisms, the signal portion is mounted in the interior of a triple metallic case. Although the cases are made practically dust-tight, it is the air partitions between the several cases that protect the signal mechanism from the effect of changes of temperature, which might lead to the deposition of moisture through condensation from the atmosphere; this has probably contributed a great deal to the success of the system, as the effects of condensation on the signal mechanism would be most deleterious. Almost from the outset the Gamewell Company decided not to use mechanisms maintained in motion by electrical means. In their designs the various electro-magnets are employed simply to set in action or to control the forces of springs or weights. An important feature is that of the automatic mechanical restoration of the armature lever of each electro-magnet to the "no current" position after its lever has been fully retracted by its spring; consequently an electro-magnet when energised by the closed circuit current has merely to attract its armature a very short distance. This permits the use of strong retractile springs on the armatures, and reduces to a minimum the effect of variations in the strength of the electro-magnets; the adjustments of the apparatus are, therefore, very robust, and when once properly set up rarely require to be altered. Another feature of the system is the employment of a uniform current strength of 100 milliamperes in every line circuit,

a strength which avoids the need of delicately constructed electro-magnets in the mechanisms. Reference has already been made to the principle of signalling the number of an alarm box when it is set in operation ; the adoption of the numerical code was probably a consequence of the adaptation of electrical means to do what had previously been done by hand in the manner already described. If so, it was a rather fortunate circumstance ; no more simple or certain means could have been adopted to provide against false alarms being given by reason of electrical faults occurring in the circuits, especially having regard to maintenance of the efficiency of the alarm system in many adverse conditions likely to arise in the course of its existence.

The record of the signals at the fire stations is made on a paper tape by mechanical registers punching or stabbing circular or triangular holes. These instruments are designed to make the record of each individual signal similar in size, although variations in the duration of the " breaks " of the circuit may be made by the alarm box transmitter. With a Morse Code system variations in the lengths of the recorded signals are likely to occur from this cause, and in consequence may give rise to uncertainty as to the locality of the alarm. For this reason the Gamewell System is undoubtedly superior to any in which ordinary Morse recorders are used to record signals, whether in Morse or numerical code.

In American practice it may be stated that all street fire alarm circuits in a town or city are connected to a central station where all fire alarms are received and re-transmitted—in some cases manually, in others automatically —to the engine house, hook and ladder companies, and to the other departments of the brigade. This, also, is generally the plan adopted in Germany. The object is to centralise the control of the brigade as a whole. For small towns with volunteer brigades, a fire alarm system usually consists of a single closed circuit for the street boxes (see Fig. 116), or fire telegraph stations as they are termed. The alarm circuit is connected to operate electrically and automatically either an electro-mechanical tower bell striker or an electrically controlled steam syren by which the alarm is sounded, announcing to all concerned the section of the town where the fire has been discovered. The employment of such means of spreading an alarm is not favoured by fire brigades in this country ; the adverse reason advanced being that the attention of the idle and curious would be attracted, and that this would hamper the operations of the brigade. Therefore, when a British municipality decides to make a start with electrical fire alarms, it is, as a rule, with the object of providing an electrical bell at each of the firemen's residences to dispense with the use of either maroon rockets or of large mechanical bells or hooters for spreading the alarm.

The plan of interconnecting electrically the various component items of a Gamewell fire alarm installation is quite a simple matter. The street fire alarm boxes are connected in series with each other and with the fire station receiving apparatus and the closed circuit battery proper to the particular circuit, each circuit being treated independently. It will, therefore, be sufficiently explanatory of the Gamewell system to describe separately some of the principal up-to-date items of apparatus usually employed.

Types of Fire Alarm Boxes.—Fire alarm boxes are of three general types, known as the " Interfering," the " Non-Interfering," and the " Successive."

The Interfering box (Fig. 116) has no ability to control its circuit once

it has been started in operation; and hence, if more than one box is pulled at or about the same time, a mixed, a confused, or a totally mutilated signal will result.

The Non-Interfering box (Fig. 117) is provided with devices so arranged that if two or more boxes are pulled at or about the same time—even to precisely simultaneous operation—one of them will automatically select circuit control, hold such control to the exclusion of all other boxes, and transmit its full and complete alarm of four rounds or repetitions of its

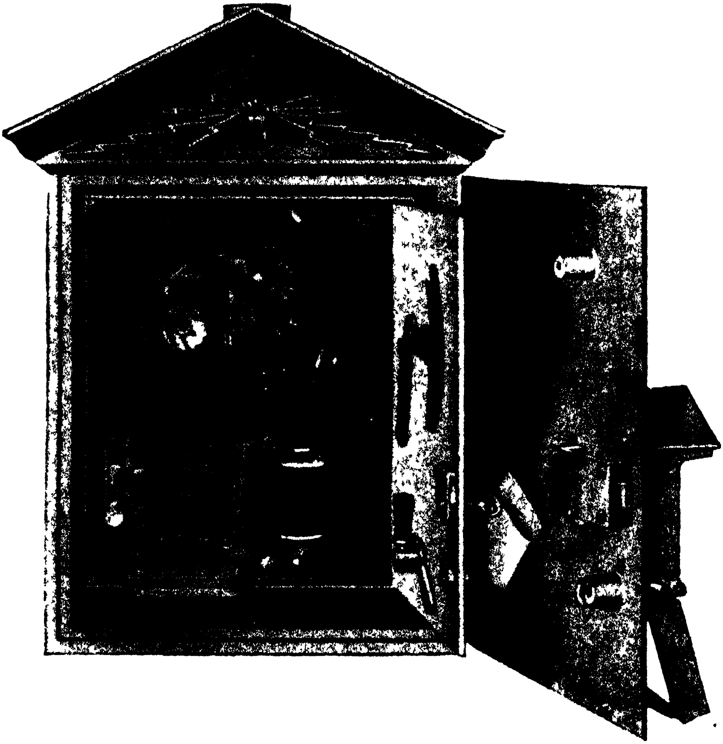


Fig. 116—Gamewell Fire Alarm—Plain Sector Type Box.

signal number. The other box or boxes failing to secure control of the circuit will not attempt to signal at all.

The Successive box (Fig. 118) is non-interfering, as just described, but has the added feature that after the box selecting control of the circuit has completed its signal the other box or boxes will automatically take control, one after the other, and signal fully and completely; hence the term "Successive."

The first alarm box ever used was Interfering. In fact, it was not then appreciated that more than one box would be pulled at about the same time for a fire; but as the fire alarm telegraph gradually came into more extended use, it was soon found that many alarms were lost through interference, and the Non-Interfering box followed; but nearly thirty years

were required before the new type of box was reliably and successively developed.

The continued extension of the fire alarm telegraph, and the growth of areas protected, shortly led to the discovery that occasionally two boxes on the same circuit were pulled at or about the same time for different fires. One of them only would signal, and much delay was caused by the necessity of having to pull the second box over again, after the first one had completed its alarm. As the person operating a box for fire frequently runs back at

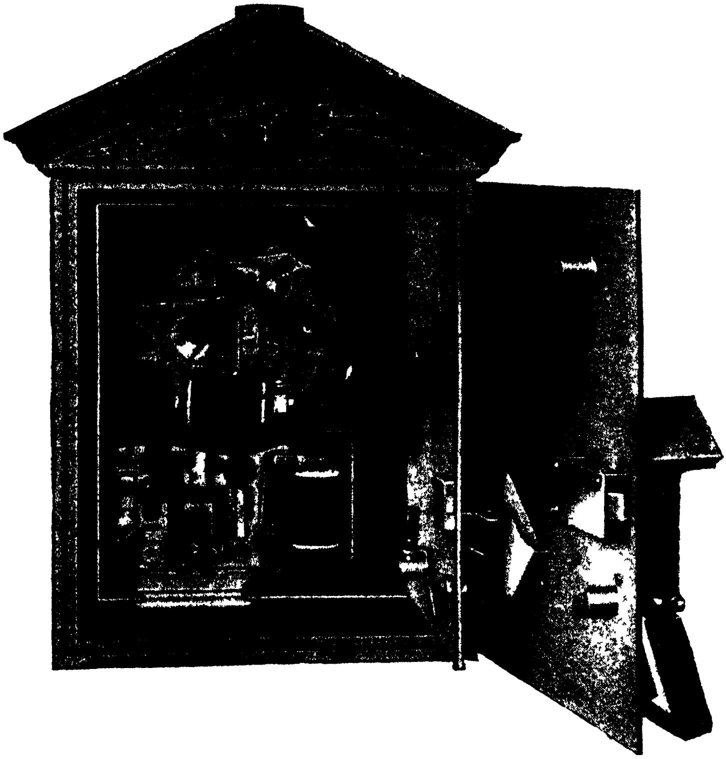


Fig. 117—Gamewell Fire Alarm—Non-Interfering Sector Type Box.

once to the fire location, the delay referred to above was a serious one. To overcome this condition, the Successive box was designed, but it took a period of about 10 years before it was in form to be safely used.

The Fire Chief will realise from the above that the use of an Interfering box in his town involves the possibility that it will not function properly in an emergency, and that a bad loss may easily result therefrom. It is sometimes said that "the chances of two boxes being pulled at the same time are remote"; but, as a matter of fact, such occurrences have been frequently happening for seventy years, not only in city fire alarm systems, but in systems in industrial properties. The very statement that "the

chances are remote," implies a gamble on the lives of people and the safety of property values if such boxes are used, which no fire chief should be willing to make.

The size of a town and the number of boxes located throughout it, has no bearing on the possibility of an interference. Interference comes through boxes adjacent to a fire being pulled at about the same time; and hence there is as much liability of an interference in a town having a few boxes as in one having many, assuming a proportionate box distribution.

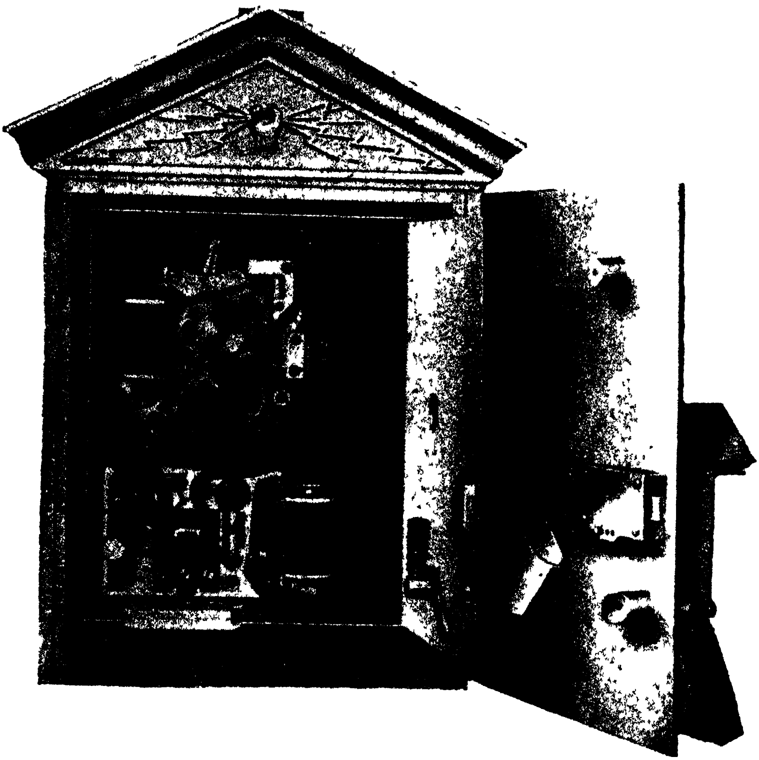


Fig. 118.—Gamewell Fire Alarm—Non-Interfering Successive Type Boxes.

The Successive feature of fire alarm boxes, has, of course, no value over the Non-Interfering feature, unless boxes operated together are pulled for different fires. In considering, therefore, whether one type or the other should be used in a given town, the area of the town should be considered, as well as the size and number of buildings, the character of their construction, and questions of use and occupancy as bearing on the fire hazard.

The latest types of box fitted with Quick Action Doors are shown in Figs. 119 and 120. With the latest type of Quick Action Door (119) which has just been installed at Hove, there is no glass in front of the handle; it is considered that the amount of time saved in not having to look round

for a stone with which to break the glass is worth more than the extra risk of the malicious call.

Central Station Receiving Apparatus.—The receiving apparatus may be divided into two classes, Recording and Audible. The recording consists of (1) a Register which punches or stabs a series of circular or triangular holes on a moving paper tape; (2) a Time and Date Stamp which automatically stamps the time and date of the call on the paper tape.

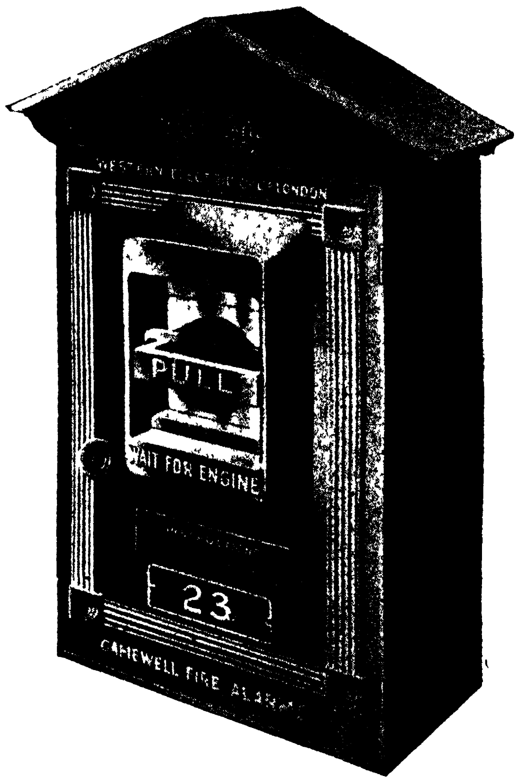


Fig. 119.—Outside of a typical Fire Alarm Box.

View showing type of Quick Action Door. It is only necessary to pull the handle to break glass and give the alarm.

The Register is made for both single and multiple circuits, but the number of alarms that can be connected to any one circuit is only restricted by the importance of that circuit and the length of lines. In practice it is not usual to put more than 20 boxes at the most, on any one circuit, although electrically any number of boxes could be connected to any one circuit.

Fig. 121 shows a Single Circuit Register with an Automatic Date and Time Stamp in position for recording and timing calls. The record o o o punched on the tape is that of Box No. 21 as will readily be seen. Each

box repeats its call three times and each time it is punched out on the tape, so that there is no possibility of error.

After a box has completed its call, the Time and Date Stamp automatically stamps the time and date on the tape.

The Audible Signal is given by an Electro-mechanical Gong (Fig. 122). Each time the Register punches a hole in the tape, one blow is given on

Fig. 120.—Outside of a typical Fire Alarm Box.
View showing type of Quick Action Door. Two operations are necessary. Break Glass and Pull Handle.

the Gong. Thus for Box No. 21 the Gong is struck twice in rapid succession, then after a short pause, once (two, one), this is repeated three times.

In towns where there is more than one fire station, each fire station has its own recording apparatus which records all calls given in the area which that particular station deals with, but all calls are transmitted simultaneously to the Central Fire Station.

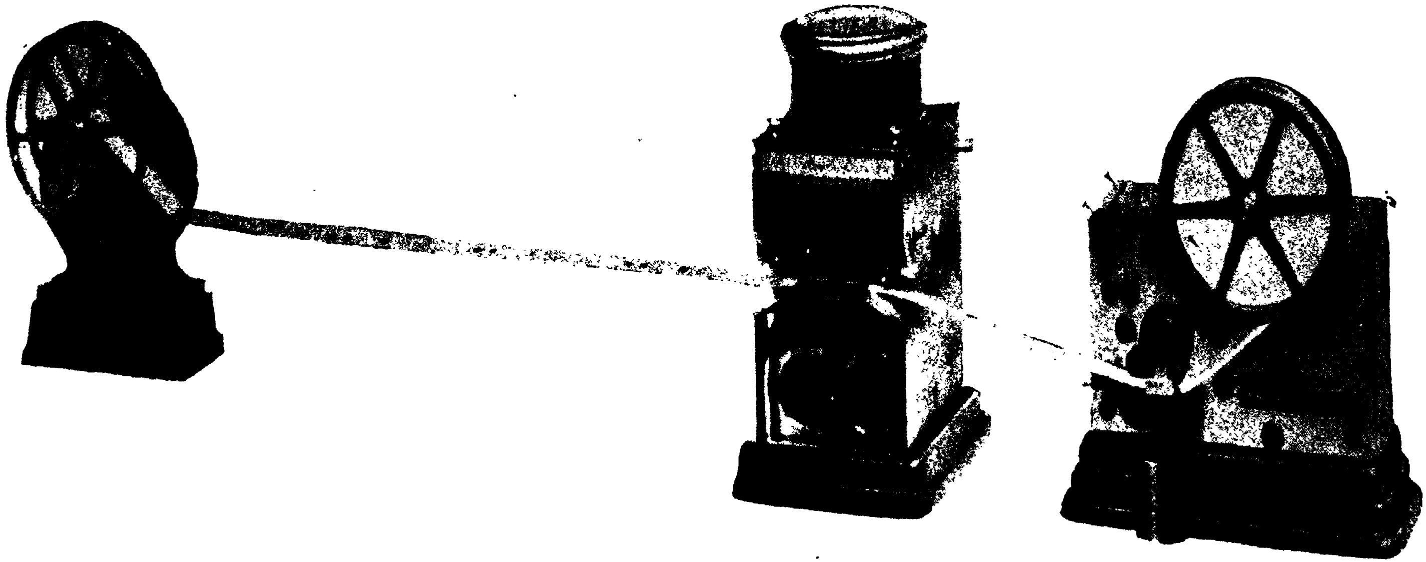


Fig. 121.—Gamewell Fire Alarm System.—Recording Apparatus.

At the Central Fire Station any call can be sent out to any or all sub-stations. This is usually done by manual transmitters, a particular type of which is illustrated by Fig. 123.

Fig. 124 shows a typical layout of a single circuit. It will be seen that all the boxes, together with the Register and Gong, are in series. A small current of $\frac{1}{50}$th of an ampere continuously flows through this circuit, and it is by the interruption of this current by the pulling of a box that causes the apparatus at the Fire Station to function. It will also be seen that as only one wire is required per circuit, how economical the Gamewell System is as regards annual rental of wire; this is a very great consideration.

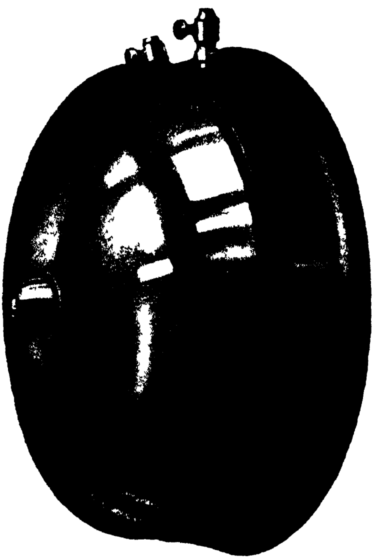


Fig. 122.—Turtle Electro-Mechanical Gong.

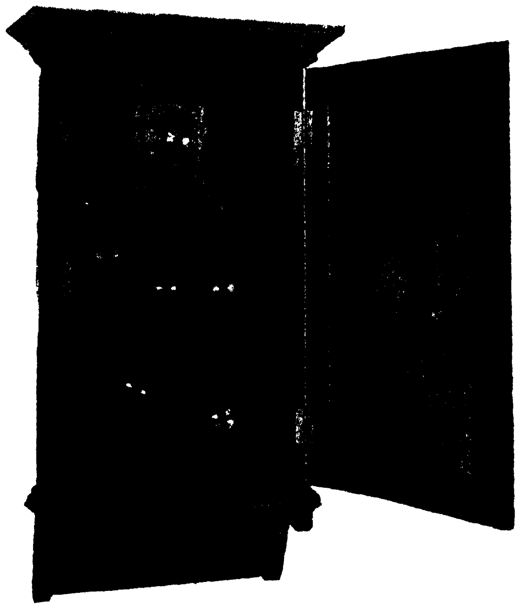


Fig. 123.—Gamewell Fire Alarm System.—Manual Repeating Box.

The power required to operate the Gamewell system is extremely small, the cost only amounts to a few pence per week.

All Gamewell Boxes are self-testing and all boxes are fitted with a special signalling key which is used by the firemen for calling up the Fire Station should further assistance be wanted. A very simple code is used, the key is depressed two, three, or four times, etc., etc., in rapid succession, indicating the kind of assistance required at the scene of operations, and the box is then pulled to indicate the locality. This code signal, together with number of box, is recorded on the tape, timed and dated same as a fire call, these signals can be arranged to practically cover any contingency.

The accompanying table is from a Fire Brigade Instruction Book showing the sections of the Brigade assigned to turn out on the reception of the 1st, 2nd, 3rd, and 4th alarms respectively, from the particular street boxes

Station.	Engine Cos.	H. & L. Cos.	Dep. Chief.	Chief of Bt.	Boat Tender.	Water Tower.	To Supply Fuel.	Fuel Depôt.	To Change Location.	Reserves. Engs.	Reserves. H. & L.	Reserves. C. of B.
487 Fulton and Front sts.	108, 124, 106	53, 68	6	21, 23	...	...	....	....	....	......	...	...
	107, 105, 103, 123, S.L.	60	...	22	6	...	Eng. 108	H. 53	....	......	...	...
	126, 104, 156, 132	55	...	24	...	6	„ 124	E. 105	H. 69 to H. 68............	......	...	...
	110, 151, 102	....	...	....	...	...	„ 106	H. 53	E. 119 to E. 126; E. 135 to E. 119; E. 139 to E. 104; E. 151 to E. 106........	......	...	...
	....	....	...	....	...	...	....	....	....	......	...	...
488 Franklin, near Noble st.	115, 112, 138	56	7	26, 35	..	...	....	....	....	......	...	...
	121, 158, 129	54	...	25	...	...	Eng. 115	H. 56	....	......	...	...
	113, 116, 159, 132, 123	65	...	24	7	...	„ 112	E. 121	H. 69 to H. 54.............	......	...	...
	111, 151, 130	....	...	....	...	...	„ 138	H. 56	E. 110 to E. 121; E. 137 to E. 113; E. 151 to E. 115; E. 160 to E. 158.......	......	...	...
	....	....	...	....	...	...	....	....	....	......	...	...
489 Franklin and Freeman sts.	115, 138, 158	56	7	26, 35	...	...	....	....	....	......	...	...
	112, 121, 129	54	...	25	...	...	Eng. 115	H. 56	....	......	...	...
	113, 116, 159, 132, 123	65	...	24	7	...	„ 138	E. 121	H. 69 to H. 54............	......	...	...
	111, 151, 130	....	...	....	...	...	„ 158	H. 56	E. 110 to E. 121; E. 137 to E. 113; E. 151 to E. 115; E. 160 to E. 158.........	......	...	...
	....	....	...	....	...	...	....	....	....	......	...	...

enumerated on the left-hand column. The 2nd, 3rd, and 4th alarms are given in the manner just stated by the fire department. The 1st, 2nd, 3rd, and 4th horizontal sets of figures in each of the other columns are the sections of the fire departments, known by the numbers shown, deputed to respond to these alarms. It may be mentioned that in all large Central Office Plants, manually staffed, the street boxes are speeded up to transmit signals with the maximum rapidity possible. Such Central Offices are, as a rule, connected with the various telephone exchanges in their respective cities, and all fire calls received by telephone are translated into numerical signals and retransmitted according to the Fire Instructions Book, the Brigades being sent to the street box nearest the outbreak of fire. It is considered nowadays advisable to equip all large offices with automatic repeaters as well as to transmit the first alarms received from the street boxes to the several sections of the fire department.

Fig. 124 is a diagram of the Installation at Hove.

Supply of Electric Current for working the Alarm System.—Wherever an electric light or power supply is available it is usual to utilise such supply to charge sets of small size accumulators to provide the currents required for the various fire alarm circuits of an installation. The Gamewell Company have designed switchboards which enable the charging of the cells to be done in an economical, safe, and convenient manner. The switchboards are made suitable for charging from any direct current supply of up to 500 volts pressure; where the supply is alternating, a rectifier would have to be provided in addition.

Duplicate sets of batteries are required for each circuit in order that one set may be charged whilst the other set is feeding the circuits.

Where no power supply is available the necessary current is obtained from primary batteries. In this case Daniell Batteries are almost invariably employed on account of the constancy of their electro-motive force.

In the United States the form of Daniell battery used for the purpose is that known as the Gravity, as its internal resistance is low. The gravity cells are mounted on racks conveniently accessible. It may be mentioned that if these batteries receive periodic frequent attention their upkeep is quite satisfactory; but it is found that in the primary battery installations maintained in this country by the Post Office that such frequent attention would be rather costly, hence the trough type of Daniell is used; two sets of troughs being connected in multiple. Even this arrangement, by reason of the loss of power due to the high resistance of the cells, is not a desirable one, and it is thought that it would tend to economy if the municipal body were to arrange for the necessary maintenance of Gravity cells to be carried out by the firemen as is done by the Blackpool Fire Brigade. It would not be a difficult task for a linesman to impart the necessary instructions and to inspect from time to time, the condition of the batteries. Where primary batteries are employed, it is desirable that underground conductors of not less than 40 lbs. copper to the mile and aerial wires of not less than 150 lbs. copper to the mile should be employed for the external wiring.

It is thought that the description given of the Gamewell Company's apparatus is sufficient to show that an extraordinary amount of mechanical skill and ingenuity has been expended in the design of the system since it was first invented, over 50 years ago. An inspection of the apparatus will

be still more convincing on this point. It may be considered at first that the mechanism employed is unnecessarily complicated for the objects to

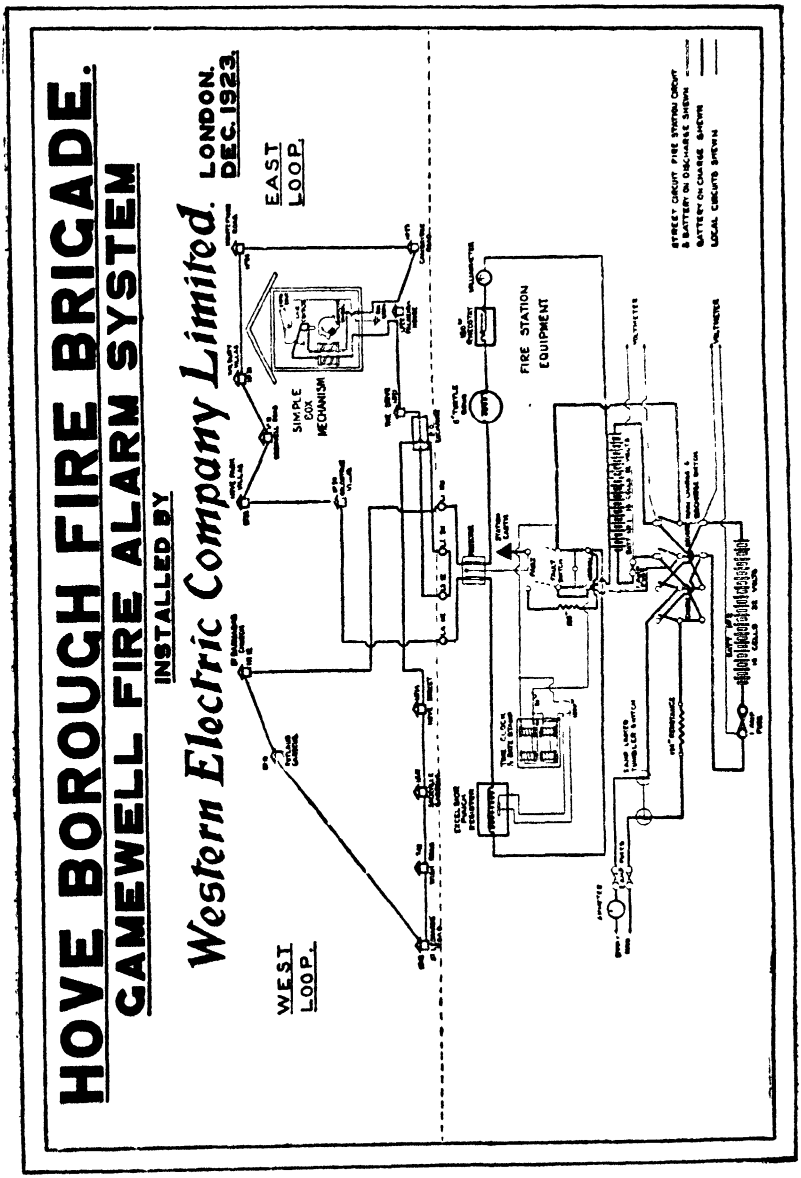


Fig. 124.

be achieved and that it resembles clockwork in its liability to be deranged easily, but there is an essential difference between the train of wheels employed in the Gamewell signal mechanism and that of clockwork. In

the latter the driving force is stepped down by the train of wheels to a strength just sufficient to impart the feeble impulse necessary to maintain a pendulum in motion. In the Gamewell wheel mechanism the force supplied to the escapement is rather strong, and judging by the experience of accurately made clockwork there is no mechanical reason why it should not continue in unimpaired condition for a considerable number of years.

As a matter of fact no case is on record of an electrical *fault* giving a fire call.

The system being a closed circuit one, it is on guard all the time, is self-testing, and a break on the circuit is instantly recorded, when the line can at once be temporarily patched, and no calls need be lost. A single earth fault would not interfere with the working of the system.

All modern boxes are constructed as "successive Non-Interfering" and any number can be connected to one circuit, but in practice the number upon each circuit is fixed by the probable risk of any breakdown of the line and the fire risk of the locality to be protected.

The closed system, such as the Gamewell, depends almost entirely upon the care with which the whole apparatus is manufactured and maintained. In America, large technical staffs are employed in connection with the fire alarm systems, but it must be remembered that this staff provides the whole of the wiring, and carries out the maintenance work in connection with the installations.

The above systems refer almost entirely to fire alarms in posts situated in public thoroughfares so that the public may communicate from the posts to the Fire Station. These posts should be placed at the corners of streets in conspicuous places, and it has been found that their erection on sites near the pillar boxes to which the inhabitants of the district are in the habit of going to post letters, tends to impress upon the minds of the public the position of the fire alarm. The post office endeavour, if possible, to have a lamp post sufficiently near the pillar box to throw a good light over the "Times of Collection" plate. The ideal arrangement would be to have fire alarms at the corner of every street, but even if one were placed near each pillar box a town would be amply protected. The glass in the street lamp should be partly coloured red if only to the extent of a 2-inch band, as it is found that the public soon understand this useful method of indicating the position of a fire alarm. It must be remembered the darkest part of a street is that just under a street lamp, and therefore, to obtain a good light on the fire alarm head a distance of 9 feet from lamp post to fire alarm has been found most satisfactory.

In Great Britain the Postmaster General has the monopoly of telegraphic communication, and telephones are not outside the limits of the exercise of his authority. Therefore, it is the usual procedure for a municipal authority to apply to the Post Office to instal a fire alarm system. The department will, however, provide open, closed, or, in fact, any system according to the desire of the applicants, so that it is unnecessary to give more detailed description than that set out of the various appliances. Each system may have certain good points and in various districts one design may be more suitable than another.

Another system, which is much favoured by those using it, is one that consists of a combined fire alarm and telephone. This enables the public

to call the brigade by breaking the glass and pulling the alarm in the usual manner, and also, by the use of keys, the police and the corporation employees are able to communicate with their several departments at the Town Hall. It is claimed that by means of these telephones a large amount of time has been saved when Inspectors or Foremen require instructions from their chiefs, or supplies of materials are urgently required for carrying on the public services, and the Police can obtain extra help in case of need.

It may not sound strange to relate that "wireless" was employed in fire brigade work as long ago as 1900. Unfortunately it was not the success which might be expected to-day. Pending the erection of a permanent fire station in the locality, a temporary station had been established at Streatham in South London, and a private house some little distance away was adapted for the residential accommodation of the men. The local authority objected to overhead wires being run between the duty station and the men's

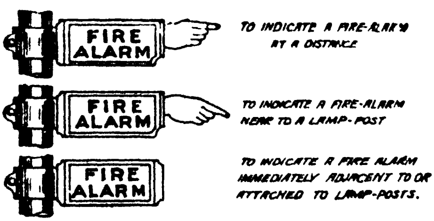


Fig. 125.

Fig. 126.

quarters, and the cost of installing underground cables rendered the project prohibitive, therefore it was decided to instal a wireless telegraphic system.

The lack of success was no doubt due rather to the inefficiency of the operators than anything else, but it is believed that with better knowledge as to the tuning up of instruments, etc., the results to be obtained would be such as to justify larger and more interesting experiments in this method of fire alarm communication.

Considering the great impetus "wireless" has received during the last few years, and the number of persons in possession of receiving sets, no difficulty should be experienced in perfecting a wireless system that will enable firemen to communicate with their fire station by means of an instrument carried upon a fire appliance. On 28th February, 1923, the Postmaster-General stated "he was prepared to consider applications from Fire Brigade Authorities for permission to use wireless for communications between a fire station and a portable station on a fire engine during the progress of a fire and when line communication is impracticable. A wave of 320 (c.w. or telephony) metres would be allotted for such communication."

In 1906 Indicators in the form of a pointer shaped like a hand, and painted red, were fixed to lamp posts adjacent to fire alarms throughout the County of London, the City corporation and the metropolitan borough councils agreed to fix and maintain these indicators, the County Council supplied castings of three patterns as shown in Fig. 125.

In 1908 fire alarms in use in the East End of London were provided with tablets fixed above the head of the post with instructions in Yiddish, as it was alleged many of the inhabitants could not speak English, and although it was doubtful whether many could read Yiddish it was hoped, by this means, the residents in that part of London would be materially assisted in ascertaining the position of the fire alarms and learn to use them in an intelligent way should occasion arise. Fig. 126 shows an alarm post head.

Automatic Sprinklers.—Experiments were carried out publicly in Stockholm late in the 18th century which demonstrated that fire could be extinguished by the application of either a mixture of certain earths and water or by even very small quantities of water alone. The latter experiment, that of using very small quantities of water alone, further showed that for this method to be effective the water must be applied to the hottest part of a fire so that it could be diffused in the form of steam.

It seems probable that the frequent occurrence of large fires caused the subject of fire protection to be forced on thinking minds.

The movement for the greater development of the municipal or corporate activities of communities, though only in active operation in the largest towns, was slowly spreading, and people began to realise how unprepared they were for the ravages of large conflagrations. Whatever caused this awakening, it is noticeable that the introduction of sprinklers moved at first very slowly in public favour, and very few townships had a really good fire service, and subsequent developments were left more to private enterprise than to corporate endeavour. Sprinklers were no exception to the rule. In fact, it is quite safe to say that had it not been for a favourable inducement extended by the Fire Insurance Companies to their clients who would instal sprinklers, it is not at all unlikely they would soon have passed into oblivion without ever having the opportunity of proving their great utility in the prevention of the spread of fire.

Sir S. Bentham, in 1797, conceived the idea of using small jets of water to extinguish fire, and elaborated a system which undoubtedly was the forerunner of our present day sprinklers.

His system consisted of large tanks on the tops of buildings from which iron mains were run to the premises to be protected. From these mains smaller perforated pipes were led along the underside of roofs, and so arranged that water could be projected over the whole of the protected area. It was necessary, however, that the water should be turned on by the operation of a cock.

This system was installed in the London and South-Western Railway Company's Works at Nine Elms, London, and it is believed that the pipes were still in position at the time the buildings were demolished a few years ago.

The principle thus initiated by Sir S. Bentham was improved by Sir

W. Congreve, who, in October 31st, 1812, obtained a patent No. 3,606. (See Figs. 127, 127*a*, 127*b*, 127*c*).

The inventions of Bentham and Congreve were further improved upon by Stewart Harrison, who in 1864 introduced the sprinkler head. Hitherto there had only been perforations along the pipes, and no water could be played on a fire until a handle or cock had been turned to release the water in the cisterns at the top of the building. Harrison's improvement made it possible for the pipes to be always fully charged. There was of course, a distinct advantage in this, as it was not necessary for a person to be always in attendance. The new sprinkler head was self-acting. It was placed at 6 feet (1·8 m.) intervals along the pipes and fitted with valves; the pipes being 6 feet (1·8 m.) apart, an area of 36 super feet (3·3 m.^{2}) was protected.

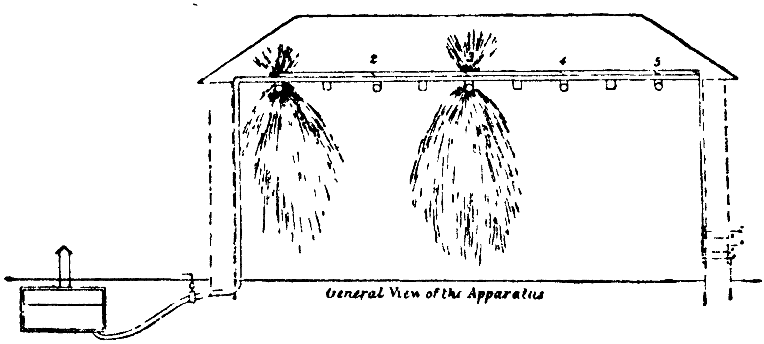


Fig. 127.

Fig. 127*a*.

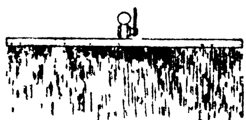


Fig. 127*b*.

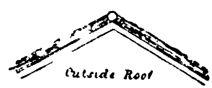


Fig. 127*c*.

The sprinkler head (Figs. 128 and 129) consisted of a bulb in two parts perforated in the upper and lower sections in such a manner as to distribute the water as equally as possible over the whole of the area it protected.

In the lower half of the bulb was fitted a small boxwood stem which held the valve in position, the boxwood stem being itself held in position by a fusible metal wedge.

The metal wedge (Fig. 130) was set to melt at about 212° F. (100° C.), and on operation released the spindle and thus allowed the valve to be forced out by the pressure of the water. When the water commenced to flow through the mains, a piston was actuated which connected an electric circuit attached to an alarm bell placed near the watchman's box or in some other conspicuous place.

The introduction of Harrison's sprinkler head, and the earlier inventions of Bentham and Congreve, mark the beginnings of the present day sprinkler systems. They have been kept fairly distinct by the special needs of the

case for their adoption, and generally speaking Bentham's and Congreve's systems fall under what is called to-day the Dry-pipe system, and Harrison's comes under the Wet-pipe system. There are special circumstances which make one or the other alternatively the better to instal, but the Wet-pipe system is the more usual in this country.

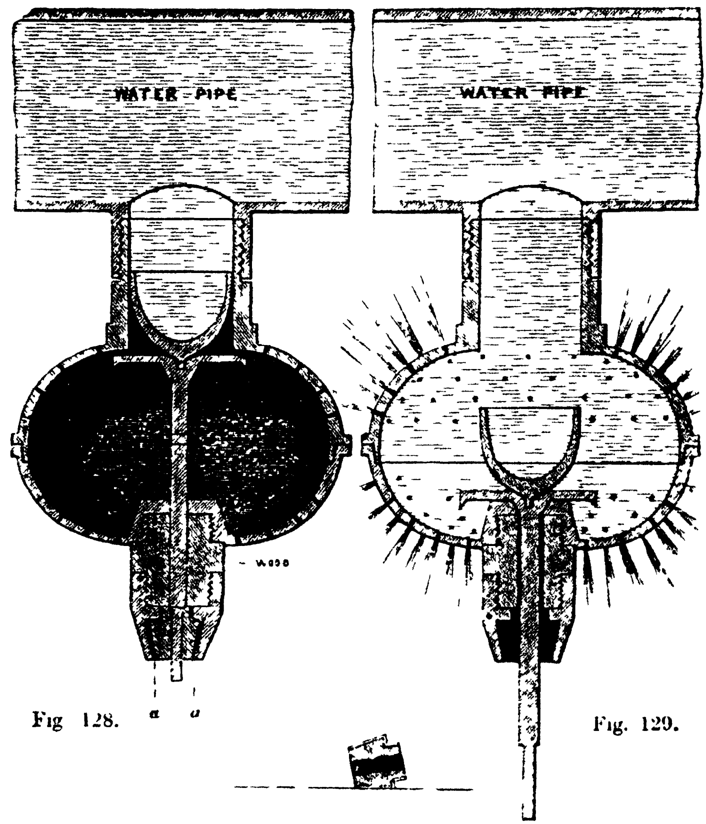


Fig 128. Fig. 129.

Fig 130.

Wet-Pipe System.—In America, about 1874, a sprinkler was designed by a Mr. Parmalee (Fig. 131); it was introduced into England some seven years later, and in course of time became the first of this type of apparatus to obtain recognition by an Assurance Company, and to obtain a discount from the fire premium. Parmalee's sprinkler was of the valveless sealed type, a cap soldered to the head confined the water until such time as the heat was sufficient to raise the temperature of the water to melting point of the solder. Parmalee's sprinkler having succeeded in obtaining financial acknowledgment, some 40 to 50 others in many varied forms were soon upon the market, including the "Vulcan," from Manchester (Fig. 132), but all suffered from the tendency of the caps to stick. It had to be

admitted that the design was wrong, and the sealed type became obsolete.

Mr. Grinnell, an American, invented and introduced into England in 1884 the first of the valve type (Fig. 133), which, unlike the sealed type, was arranged so that the solder was reduced to a small quantity and kept well away from the water. The new valve type soon had many imitators, and many of the subsequent designs have been incorporated in the patterns now in general use. The principal points required in an efficient sprinkler are—

Simplicity in design,
Mechanically strong,
Maximum sensitiveness in the fusible joint,
Freedom from the action of water,
Proof against leakage, and
Giving an equal distribution of water over the area it is to cover.

The assurance companies have a staff of experts who examine new inventions and from time to time test samples of the admitted types to

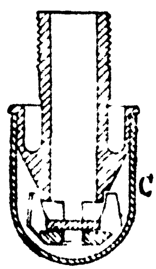


Fig. 131.
Parmalee Sprinkler.

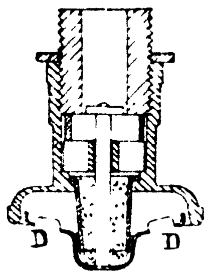


Fig. 132.
Vulcan Sprinkler.

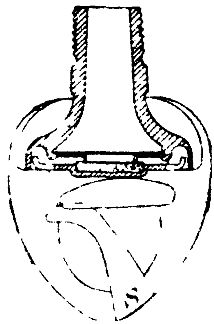


Fig. 133.
Grinnell Sprinkler.
(*Obsolete.*)

ensure that the standard of manufacture is kept up. There is a selection of sprinklers in use and others are being constantly placed upon the market, and submitted to the Fire Offices Committee of the Assurance Companies for approval.

It is considered by many experts that the fusible joint should be kept clear of the water, and be so arranged that the parts when released fall outside the head.

The solder is generally arranged to melt at 155° F. (68·3° C.), and an alloy composed of—

50	per cent.	Bismuth,
25	,,	Lead,
13	,,	Cadmium,
12	,,	Tin,

is said to give good and even results.

In cases of higher temperatures, from 210° F. (98·8° C.) and upwards, such as are found in stoves, drying rooms, near furnaces, etc., other alloys are used.

Dry-Pipe System.—In buildings not artificially heated, with the probability of the water in any pipes freezing, the dry-pipe system should be adopted. In this case instead of the pipes always being charged with water, air under sufficient pressure is forced into the pipes to keep back the water in the supply pipe behind the valve. Upon a sprinkler opening, the air escapes and releases the pressure on the valve, which can then be forced open by the water, allowing it to flow into the pipes and on to the heads that are open. The heads must be fitted upright and above the line of pipes, every pipe having a fall towards the waste or drain pipe, to drain off all water from the installation. The system should be arranged so that not more than 700 sprinklers are controlled by one main stop and air valve.

A half-inch (0·013 m.) pipe testing tap on the installation side of the air valve should be fitted, and if an ordinary alarm valve is fixed in addition to the air valve, a half-inch (0·013 m.) testing cock should be fixed between the two valves for the purpose of frequently testing the gong.

If it is considered necessary, as it is in some districts, to have water in the sprinkler system during the greater part of the year, and then "dry-pipe" during the cold months, this can be arranged by slight alterations in the valves.

General.—All installations must have pressure gauges fixed above the alarm valve, and also below the alarm and main stop valves.

Every installation must be fitted with an automatic alarm signal to give notice as soon as any sprinkler is opened. This must be protected and tested at least once a week, except in the case of a purely dry-pipe installation.

In order to be effective, the heads must not be more than 10 feet (3 m.) apart and the installation must extend to every part of the building, such as the spaces between the ceilings and roofs, either at the apex or at the sides of buildings. The maximum number of sprinklers in these spaces need not exceed the number in the room below.

All hoists, elevators, shoots, rope or strap races, non-fireproof w.cs., gearing boxes and non-fireproof staircases, whether fitted with risers or not (including the undersides) inside or communicating with sprinklered buildings, must be protected by sprinklers.

Corn and Textile Mills, Distilleries, and a few other classes of risk require special arrangements to be made, including the placing of sprinkler heads in all exhaust trunks, boxes of elevators, over openings in the floor for ropes, belts, shafts, straps, etc.

Cases have occurred in buildings only partly protected where the water has been turned off at the valve to prevent unnecessary damage by water. Afterwards it was discovered that the fire had reached an unprotected portion of the premises, such as a space in the roof (which was unnoticed at the time). Turning off the water had placed the sprinklers out of action, and serious damage resulted before it was possible to get a sufficient supply by the fire brigade's hose to bear upon the outbreak. Therefore, it is plain that every portion of a factory building, particularly those of non-fireproof construction, must be covered by the sprinklers. A case actually occurred

where considerable damage was done, in a fireproof room, while the adjoining portions of the building, being properly protected, were saved.

Drenchers.—An Installation of External Drenchers consists of "heads" which are somewhat similar to sprinkler heads erected for the protection of openings in external walls. To be effectual, they must be of the open type—*i.e.*, unsealed.

WALLS.—All combustible parts of a wall must be protected, and where the eaves are of a combustible nature a line of drenchers must be fixed just below the eaves.

WINDOWS.—Every window or other opening in the two top stories, and other openings in each alternate storey above the ground floor, must be fitted with a drencher or drenchers, so fixed that the stream of water forms a curtain which must come into contact with the window or opening 2 feet (0·61 m.) from the top.

ROOFS.—Roofs should be protected by a line of drenchers along the ridge, and all skylights and other openings properly protected. The horizontal distance between drenchers on roofs should not be more than 8 feet (2·4 m.). Where windows or other openings of combustible materials exceed 8 feet (2·4 m.), two drenchers are necessary. The water supply rising to the level of the highest drencher in a section requires a controlling valve at the base of the main feed pipe. Each section must not control more than 72 drenchers, but these sections may be divided either vertically or horizontally to suit the building. Not more than twelve drenchers may be fixed on any horizontal line of pipe, and not more than 6 on one side of the vertical feed pipe.

Windows and other openings protected by fireproof shutters or doors also require protecting by drenchers, but where the windows are separated from each other by less than 2 feet (0·61 m.) of incombustible material they may be protected as one window, provided the drencher is so fixed as to command the whole of the opening.

As stated above, drenchers are on the dry-pipe principle, and therefore it is necessary to provide discharge pipes in order to thoroughly drain the installation. Generally, no pipe of a less diameter than 1 inch (0·03 m.) may be used for the supply of water, and those for drenchers or open pipes must be galvanised, or lined with tin or lead, or Dr. Angus Smith's solution. As far as possible bends should be used in place of right-angle junctions.

To operate drenchers it is necessary that the controlling valves are placed in accessible positions, if possible on or near the ground level, but not within the risk of the exposing hazard. They should be carefully protected against action of frost, and secured by padlocked or rivetted leather straps which can be easily severed in case of emergency.

It is of the utmost importance that the position of the controlling valves and drainpipes should be clearly indicated, and Fire Brigade Authorities should be conversant with the actual position and means of working these valves, for which purpose the Officials of the Fire Brigade should attend a periodical testing of drencher installations.

Pressure gauges must be fixed on the main supply pipes, one below and one outside the back pressure valve on the practically unlimited supply. Arrangements should also be made for the pressure near the highest drencher to be taken periodically.

Water Supplies to Sprinklers.—The following are accepted sources of supply :—

1. Town's Main.
2. Elevated Tank or Private Reservoir.
3. Pressure Tank.
4. Pump.
5. Injector apparatus in connection with public or other approved hydraulic mains, provided full particulars of the Installation have been submitted to and specially approved by the Fire Insurance Companies.

The Insurance companies standardise the discount on the premiums for automatic sprinkler installations according to the sources of supply. In any case, if the Town's main is one of the sources, a minimum running pressure must be obtainable with a 2-inch (0·05 m.) waste pipe open equivalent of giving at the level of the highest sprinkler of 5 lbs. on the square inch (0·34 atms.); whilst if an elevated tank forms one of the supplies it should contain at least either 7,500 gallons (34,057 l.) and be 15 feet (4·6 m.) above the highest sprinkler head or 5,000 gallons (22,705 l.) if it is 20 feet (6·1 m.) above.

Elaborate rules are issued by the Fire Offices Committee of the Insurance Companies, setting out in detail their requirements in connection with automatic installations, and as these vary somewhat from time to time persons anxious to obtain discount from their insurance premiums should consult the Company before embarking upon any expense.

In order to furnish an adequate water supply to a system of sprinklers, the quantity must not merely be ample to cause a stream of water to flow from each head but also with a force sufficient to cause the water to impinge strongly against the ceiling or window-head. In some cases the various frictional causes have reduced the pressure from 150 feet (4·4 a.) to 2 feet (0·05 a.).

The efficiency of sprinklers is very liable to be impaired by rust and paint. When any of the perforated drencher pipes are being painted much time and trouble can be saved by placing tacks in each of the holes and removing them when the paint is dry.

Every installation should have concise instructions, very plainly printed, how to operate the valves. The efficiency of the best planned system is commensurate with the vigilance and presence of mind of those in charge.

It is presumed that in no case will more than 18 heads of a sprinkler installation be actuated at one time, and the water supplies are based accordingly.

AUTOMATIC FIRE ALARMS.

(Thermostats and Heat Detecting Systems.)

The necessity of early information of any fire will be admitted by all. A brief description, therefore, of some of the methods used for fire detection will no doubt be of interest, and as technical terms will be omitted as far as possible, the information will, it is hoped, be of assistance to those who from time to time come into contact with this apparatus.

In many fires the discovery is not made by the occupants of the building,

and the outbreak is only revealed when it makes itself observable to the policeman on his beat or to some pedestrian, and by this time considerable damage may have been caused.

There is scarcely an occasion where a fire could not be subdued with a minimum loss to contents and fabric if an efficient Brigade could get to work within 5 minutes of the outbreak. It is, therefore, of considerable assistance to Fire Brigades to receive the early warning an Automatic-alarm System provides.

It is not generally known that Automatic Appliances are gradually making substantial headway, and a large number of premises in London and the Provinces are now fitted with one form or another of sensitive instruments that will give an alarm of fire immediately an outbreak occurs or a dangerously high temperature has been reached.

Briefly, the methods of Fire Detecting Apparatus may be separated into two classes:—Thermostats—which are instruments worked distinctively—*i.e.*, capable of being adjusted to any desired degree of temperature; and Systems of Sensitive Tube—which contain fluid or air, and in which the expansion of the contents actuates a contact at the extreme end of its run.

Thermostats are made of sensitive strips of metal formed of two or more distinct metals, which allow a rapid expansion but have sufficient "hardness"

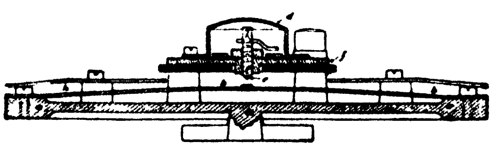


Fig. 134.

or springiness to ensure the return of the strip to its normal position when the temperature falls.

One of the most practical forms of this type, adopted about 1903, is illustrated in Fig. 134.

(*b*) is the sensitive strip supported upon an iron casting (*a*). Heat expands the strip outwards until contact is made at the point (*e*) which can be set to any degree desired.

An improved form of this instrument is provided with two sensitive strips. The use of a second strip enables a margin of setting, say 25° F. (14° C.), to be maintained at any degree whether at 30° F. (−1·1° C.) or 160° F. (71° C.) if the rise or fall is due to normal temperature variations. An outbreak of fire has only to increase the temperature around the instrument a little over 25° F. (14° C.) to cause it to make contact. The contacts of this instrument are sealed in an iron chamber which prevents any dust or moisture collecting on the surfaces and thus retarding their action.

Tube Systems are being used to a considerable extent as they are much neater in appearance than thermostats, and are not likely to be damaged or displaced by a blow from passing goods. Fig. 135 shows the full size of tube used, approximately $\frac{1}{16}$ of an inch (0·0025 m.) in diameter.

The One Tube System is actuated by the expansion of air contained within it. The tube terminates in a sensitive diaphragm (formed like those used in the ordinary aneroid barometer, see Fig. 5), which is forced up to

an electrical contact when the air in the tube has been expanded by the heat from a fire.

To ensure that normal temperature rises do not actuate the alarm, a small leak valve is provided at the junction of the tube with the diaphragm, and this allows the release of the slight pressure caused by temperature variation.

A somewhat similar System, but one of more solid construction, is that

Fig. 135.

in which the tube is filled with a fluid. In this case provision for normal increases of temperature is made by using two diaphragms, one at each end of the tube circuit; both diaphragms are built side by side and each support a contact. Normal rises in temperature distend both diaphragms similarly, but by a special valve in one (shown on the left-hand side of Fig. 136), a sudden pressure caused by an outbreak of fire forces one diaphragm up more quickly than the other and the contacts are brought together. Fig. 136 shows the diaphragms in the normal position, and Fig. 137 after being actuated.

There are other forms of detectors, but these are either obsolete or used

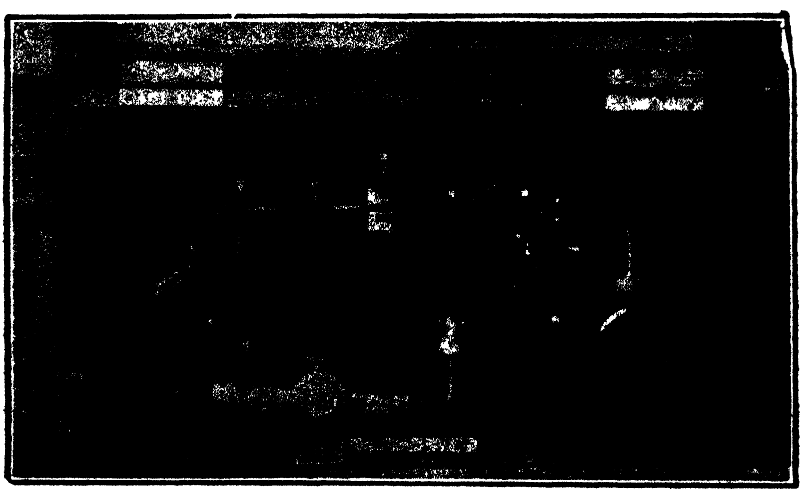


Fig. 136.—National Tubular Detector (normal).

so infrequently that there is no occasion to elaborate upon their description.

In one a steel bar supports a copper wire which has a carbon contact suspended from it. Heat expands the copper wire which lowers its contact on to another fixed beneath it.

There is also one type which has a twist of flexible wire taken around a fusible metal ring. Upon the heating of this ring the metal melts and allows the release of the flexible wire which drops a weight upon a pair of contacts.

A more recent device is one in which it is necessary to run a series of gas pipes through the premises, and at various positions a container is fixed over a small bye-pass. This container holds a diaphragm which is kept expanded by the heat of the gas jet, and this expansion keeps a pair of contacts apart. The smoke rising from a fire passes into the container nearest to it, and chokes out the gas jet. When the diaphragm has cooled as the result of the gas heat being removed, the contacts come together and give the alarm.

When fitted in position, Automatic Heat Detectors are fixed to the ceilings at distances varying from 20 feet (6 m.) to 40 feet (12 m.) apart, according to the type of instrument, and half these distances from partitions or outside walls.

The instruments are connected by cables run in casing to an indicator

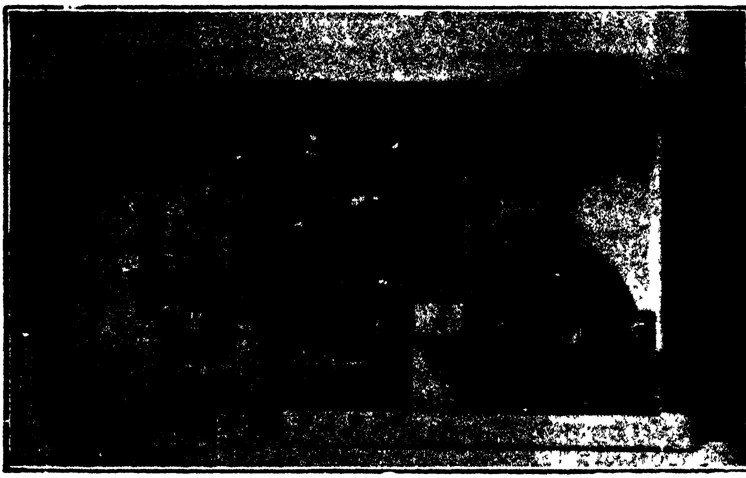


Fig. 137.—National Tubular Detector (after use).

board which consists of a number of shutters, test keys, and signalling apparatus for calling the Fire Brigade. On the outside of each protected building a loud-sounding fire gong is fixed, to call attention and to indicate the entrance nearest to the indicator board.

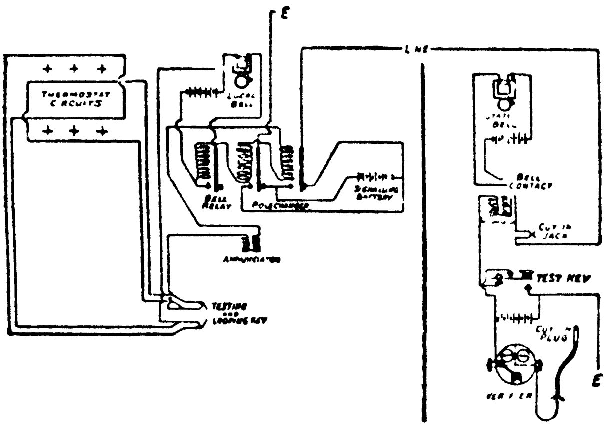
In most cases a telegraph wire connects the premises with the Fire Brigade. Signals are given by Morse telegraphs which print on a tape machine at the Fire Station a code signal—or by the simple reversal of a battery at the building equipped.

This latter method is the most used, and is undoubtedly the simplest form of warning, as there are no clockwork parts to be wound and no code messages to be confused. The warning is received upon a dial which, when a fire occurs, shows "Fire," and the indicator of the particular building involved, falls and shows the address of the premises.

A diagram, Fig. 138, of the method is given here. The circuits from the building to the Fire Station can easily be traced.

Discounts from Insurance Premiums are granted by all Fire Insurance Offices where premises are protected with approved alarms, but a wise proviso is made that the installing Company shall make tests by qualified men at quarterly or monthly periods to ensure that the apparatus is kept in an efficient condition.

Automatic Alarms calling the Brigade at the inception of a fire, in addition to reducing the loss occasioned by the outbreak, are a means of preventing much damage by water if Automatic Sprinklers have been installed, and many buildings already equipped with sprinklers are now also fitted with automatic alarms.



RISK. FIRE STATION.

Fig. 138.

The requirements of a successful Automatic Alarm System may be briefly summarised :—

(*a*) They should be sensitive enough to act quickly.
(*b*) Durable enough not to be easily put out of action by dust or corrosive atmosphere, and
(*c*) Accurate, that reliance may be placed upon their action when needed.

These alarms have an undoubted future before them, and their use should be encouraged in every way by local authorities, inasmuch as they increase the efficiency of the Fire Brigade, obviate unemployment by preventing the interruption of business which would necessarily follow a fire, and, what is to each township at the present time of vital importance, ensure that the rateable value of the building shall remain unimpaired.

Unlike watchmen, automatic alarms never sleep, do not smoke or light matches. Actually they represent invisible eyes watching every part of the building, and at the same time are ever ready to convey through their " nerve system " of wiring, an intimation to the " brain " of the apparatus, the indicator and bell, that an outbreak of fire has occurred and trained help is needed.

CHAPTER X.

PUMPS—FIRE ENGINES, STEAM, MOTOR, AND MANUAL.

Pumps.—The principle upon which pumps are worked has been known for centuries. The date of the discovery is sunk in antiquity, but the actual manufacture of pumps can be traced to a time long before the Christian Era. Indeed there is good evidence that the people of Babylon, Nineveh, and Tyre were not ignorant of the science of hydraulics, and it is well known that the Egyptians diverted the course of the Nile—a feat which even in our day gave engineers much cause for anxiety during the construction of the Assouan Dam.

However, so far as extant records can prove, it was Ctesibius, an engineer of Alexandria, who may be credited with having invented the first force pump. Hero of Alexandria, in his writings, describes this invention, and Vitruvius gives minute details of a machine for raising water to a great height, which he expressly ascribes to Ctesibius.

Details of this early invention may be found in Mr. Bennet Woodcroft's translation of the original treatise, together with a copy of the drawings (see Figs. 139, 140, and 141). This apparently is the only translation of the original Greek into English, but there are translations from German versions of the original. This is an important matter to note, because the pump ascribed to the inventive genius of Ctesibius is called, in the German translations, Hero's Engine, and, inasmuch as Ctesibius' work is independently noticed by Vitruvius, who does not even refer to Hero, it would appear to be more accurate to give Ctesibius the credit of the invention. However, the error has been repeated by subsequent writers.

The essential principles of the different early water pumps are well known to engineers. Even to-day, except for the finer workmanship, which has improved owing to a better knowledge of the use of materials and how to fashion them, there is really very little difference in the principle of arrangement of cylinders in a double purchase manual pump from that which Ctesibius constructed in the second century before Christ.

It may be considered that, in view of the antiquity of the force pump, very little could be achieved by a recapitulation of its features and design. This may be the argument of the established engineer, but it surely should not quench the ambition of the rising generation, who always desire to emulate the efforts of those who have gone before, and who would, therefore, be most likely to realise some benefit by a restatement of former achievements. At the same time a further purpose may be served in correcting mis-statements which have appeared from time to time.

Vitruvius' description is thus :—

"A hollow globe, or other vessel, may be constructed, into which, if any liquid be poured, it will be forced aloft spontaneously and with much violence, so as to empty the vessel, though such an upward motion is contrary

to nature. The construction is as follows :—Let there be a globe, containing about 6 colylæ (3 pints), the sides of which are of metal plate, strong enough to sustain the pressure that will be exerted upon them by the air. Let A B (Fig. 139) be the globe, resting on any base C. Through an aperture in the top of the globe insert a tube, D E, soldered into the globe at the aperture, and projecting a little above it; and reaching to the other extremity, except for an interval sufficient for the passage of water. At its upper extremity let the tube D E branch into two tubes, D G and D F, to which two other pipes G H K L, F M N X are fastened transversely, communicating with D G, D F. Again, into these transverse pipes, and communicating with them, let another pipe, P O, be fitted, from which a small pipe, R S, projects perpendicularly, communicating with it, and terminating in a small orifice at S. If, then, we take hold of R S and turn round the tube P O, the connection between the corresponding holes will be shut off, so that the liquid which is to be forced up will have no outlet. Now, through another aperture in the globe, let another tube, T U Q, be inserted, closed at the lower extremity, Q, and having a hole in the side near the bottom at W. In this hole must be fixed a valve, such as the Romans call *assarium*, the construction of which we will explain presently. Into the tube T U Q insert another tube, Y Z, fitting tightly. If the tube Y Z be drawn out, and water poured into T U Q, it will enter the vessel through the aperture W (the valve opening into the interior of the vessel), and the air will escape through the pipe O P, which communicates, as we have explained, with the apertures of the pipes G H K L and F M N X. When the globe is half-full of liquid, turn the small tube R S, so as to break the connection between the corresponding apertures, then depress the tube Y Z and drive out the air and liquid collected in T U Q, which will, on the exertion of some force (as the vessel is full of air and liquid) pass through the valve into the hollow of the globe; and this passage is made possible by the compression of the air into the void spaces dispersed among its particles. Draw up the tube Y Z in order again to fill T U Q with air, and then, depressing it again, we shall force this air into the globe. By repeating this frequently we shall have a large quantity of air compressed into the globe; for it is clear that the air forced in does not escape again when the rod is drawn up, as the valve, pressed on by the air within, remains closed. If, then, we restore the pipe R S to its upright position, and re-open the communication between the corresponding apertures at L and X, the liquid will now be forced out, as the condensed air expands to its original bulk and presses on the liquid beneath; and if the quantity of condensed air be large, it will drive out all the liquid, and even the superfluous air will be forced out at the same time.

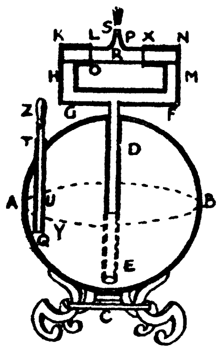
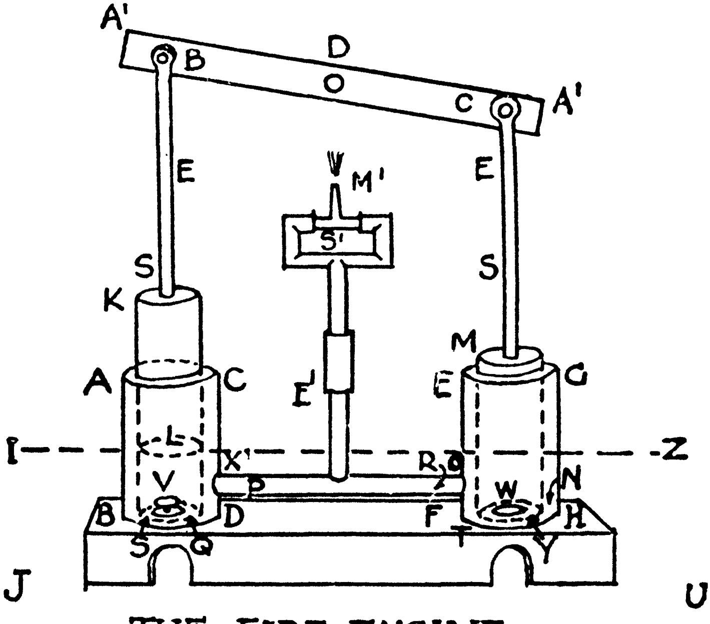


Fig. 139.
Water jet produced by Mechanically Compressed Air.

"The siphons used in conflagrations are made as follows :—Take two vessels of bronze, A B C D, E F G H (Fig. 140), leaving the inner surface bored in a lathe to fit a piston (like the barrels of water-organs), K L, M N being the pistons fitted to the boxes. Let the cylinders communicate with

each other by means of the tube X O D F, and be provided with valves, P R, such as have been explained above, within the tube X O D F, and opening outwards from the cylinders. In the bases of the cylinders pierce circular apertures, S T, covered with polished hemispherical cups, V Q W Y, through which insert spindles soldered to, or in some way connected with, the bases of the cylinders, and provided with shoulders at the extremities that the cups may not be forced off the spindles. To the centre of the pistons fasten the vertical rods S E, S E, and attach to these the beams A^1A^1 working at its centre, about the stationary pin D, and about the pins B C at the rods S E, S E. Let the vertical tube S^1E^1 communicate with the tube X O D F, branching into two arms at S^1, and provided with small pipes



THE FIRE ENGINE.

Fig. 140.

through which to force the water, such as were explained above in the description of the machine for producing a water jet by means of the compressed air. Now, if the cylinders, provided with these additions, be plunged into a vessel containing water, I J U Z, and the beam A^1 A^1 be made to work at its extremities, A^1 A^1, which will move alternately about the pin D, the pistons, as they descend, will drive out the water through the tube E^1S^1, and the revolving mouth M^1. For when the piston M N ascends it opens the aperture T, as the cup W Y rises and shuts the valve R, but when it descends it shuts T, and opens R, through which the water is driven and forced upwards. The action of the other piston K L is the same. Now the small pipe M^1, which waves backward and forwards, ejects the water to the required height, but not in the required direction, unless the whole

machine be turned round, which on urgent occasions is a tedious and difficult process. In order, therefore, that the water may be ejected to the spot required, let the tube E^1S^1 consist of two tubes, fitting closely together lengthwise, of which one must be attached to the tube X O D F, and the other to the part from which the arms branch off at S^1, and thus, if the upper tube be turned round, by the inclination of the mouthpiece, M^1, the stream of water can be forced to any spot we please. The upper joint of the double tube must be secured to the lower, to prevent its being forced from the machine by the violence of the water. This may be effected by holdfasts in the shape of the letter L, soldered to the upper tube, and sliding on a ring which encircles the lower."

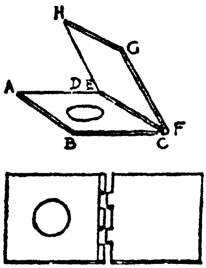


Fig. 141
Valve for a pump.

The early machines were doubtless transported from place to place upon sledges, or carried by men using long poles, in the same way as a sedan chair, or the pumps might have been carried in the same way as they are even now in Turkey (see Fig. 142). It should be noted that Hero expressly mentions that the water was forced

Fig. 142.—Turkish Fire Company.

out by the compressed air. The air vessel is shown to be of small size with the lower end of the discharge tube under water.

Fig. 141 shows the construction of the valve referred to in Fig. 140. "Take two rectangular plates of bronze of the thickness of a carpenter's rule

and measuring about one finger's breadth ($\frac{7}{10}$ of an inch) on each side. When these have been accurately fitted to each other, polish their surfaces so that neither air nor liquid may pass between them. Let A B C D, E F G H (Fig. 141) be the plates, and in the centre of one of them, A B C D, bore a circular hole about $\frac{1}{3}$ of a finger's breadth ($\frac{1}{4}$ of inch) in diameter. Then, applying the side C D to E F, let the plates be attached by means of hinges, so that the polished surfaces may come together. When the valve is to be used, fasten the plate A B C D over the aperture, and any air or liquid forced through will be effectually confined. For, by the pressure exerted, the hinges move, and the plate E F G H opens readily to admit the air or liquid; which, when closed in the air-tight vessel, presses on the plate E F G H, and closes the aperture through which the air was forced in."

Vitruvius mentions that the cylinders and valves used in connection with the pumps or bellows of the Roman water organ were also incorporated in the construction of force pumps.

The pistons were accurately turned and the faces of the valves were covered with strips of unshorn sheep-skin.

In the light of this early invention it is somewhat surprising to learn what a stir was created in the early part of the eighteenth century by the idea of using an air vessel in connection with force pumps. Indeed, the "new idea" (see Newsham's patent, p. 296) was hailed as a great invention, although Ctesibius employed this device 2,000 years ago, and Germany had been in possession of translations of Vitruvius' description of it for 200 years—*i.e.*, since 1583.

The development of the principles enunciated and worked out by Ctesibius seems in the first instance to have concerned this country very little, if at all. Of all the early improvements introduced, hardly any emanated from this country, primarily because there were in England at that time very few engineers, and again because our knowledge of metals was exceedingly limited. It would seem as if the English people deemed it more expedient to provide recompense for damage by fire than to incur the expense of an efficient system of extinction.

The Romans may have had some of their "sipho" or squirts (see Fig. 207) in London during their occupation of Britain from A.D. 43 to A.D. 410. Upon the withdrawal of their legions, London was at the mercy of the Saxons and Picts, who attacked from the sea and the north. After A.D. 410 the only mention of London during the next 200 years that can be found is that the Britons, after being defeated by the Saxons at Crayford, were driven back across London Bridge in A.D. 457. After that date, history is silent, and no record of a single building of the substantial Roman period has survived, only the wall remains, and that in a ruinous condition. In 604 the Saxons were in possession of a rebuilt city, and it is quite conceivable that for the two centuries during which the site of the city had lain waste, all the Roman appliances were lost.

The Roman occupation of Britain was followed by a long period of stagnation. So accustomed had the inhabitants become to acting as the hewers of wood and drawers of water that they were nearly helpless when any occasion arose in which combined mutual assistance was required. For many years they were not even able to repel the raids made by small parties of their enemies by sea or by land.

The political state of England under King Alfred underwent a change for the better, but the Saxon dynasty with its local government had in turn to give way to the Danes under Canute.

The advent of the Duke of Normandy (William I.) in 1066 changed the whole system of government of the country by placing in the hands of the Barons and the French Bishops absolute power within their own domains. The old English Clergy were replaced by members of the monastic orders of middle Europe.

England then entered upon the period known as the "dark ages," when general superstition existed throughout Europe owing to the gross ignorance of the whole population. A very few of the monks had any ability beyond their ecclesiastical duties, and those few mostly kept their information within the monastry walls. In case of fire they preferred to reap the advantage for the church of the charges and fees paid for the use of relics and the tolling of the consecrated bells. The lay public was taught that the procession of the holy symbols and the sound of the church bells was more effectual in expelling the evil fire spirit and reducing the fire than spending money in providing apparatus for extinguishing fires by water. Even to-day in remote country districts a popular belief exists in the efficacy of talismen at fires. In order that the above suggestions may not appear overdrawn, the following episode is given from an account by Commodore Porter, of the U.S. Navy, in his "Constantinople and its Environs." He relates an anecdote of his visit, which took place about 1835. "When the Capudann Pacha heard that a Mr. Eckford, of the U.S., had arrived at the Bosphorus in a fine ship with a fire engine on board that required twenty men to work it, he exclaimed, 'Mash Allah, let us see it.' The engine was removed from the ship to the Navy Yard, and by using a short suction, water was pumped from the Bosphorus and inundated the yard; the Pacha, fearing the Bosphorus would run dry, exclaimed, 'Mash Allah, very good, it will not do for us, as it will require the sea to keep it supplied with water, and as there is no sea in the middle of the city, they had better use their squirts. The fire may spread until the wind changes, or it is tired of burning.'"

The awakening of Municipal corporate life in the free cities of the middle and southern parts of Europe led the citizens, not only to protect their property by armed forces against their neighbours, but also to devise means to combat that good servant and bad master, Fire. As mentioned earlier (p. 275), translations of Hero's account of Ctesibius' inventions had been made from the original Greek into Italian and German. The latter was printed in 1548. It is, therefore, not surprising that the free cities of Germany which had encouraged the study of National Science to a considerable extent should be the first to adapt and use the early types of force pumps for fire extinction.

A goldsmith of Friedburg, named Anton Plater, constructed fire engines for the city of Augsberg about 1518. They were called instruments for fires, or water syringes for use at fires, and must have been of considerable size, as they were transported upon wheels. In "Besson's Theatre des Instruments" a drawing of a syringe engine (Figs. 143 and 210) is shown that must have been made before 1568, as that is the date he obtained permission to print his book. It may have been upon similar lines to that constructed by Plater for Augsberg.

Lucar's cylinder had a capacity sufficient to contain a barrel of water, and was placed upon a carriage for transport. The cylinder was filled through a funnel on the top, from a vat or dam, which in turn was supplied with water by persons carrying buckets. When the cylinder was full a stop-cock fixed under the funnel was closed and the water ejected by turning the screw and forcing the piston forward. This gave a fairly uniform jet. After the water was driven out, the stop-cock was re-opened and water again poured in through the funnel, while the screw was revolved in the reverse way and the piston withdrawn to its full extent. When full, the cock was closed and the syringe again ready to be discharged.

As the principle of the "ball and socket" or "goose neck," or even the joints described on p. 277 and Fig. 140, were apparently not known it was necessary, in order to alter the direction of the jet, to move the whole of the carriage, and to raise or lower the cylinder as required. The

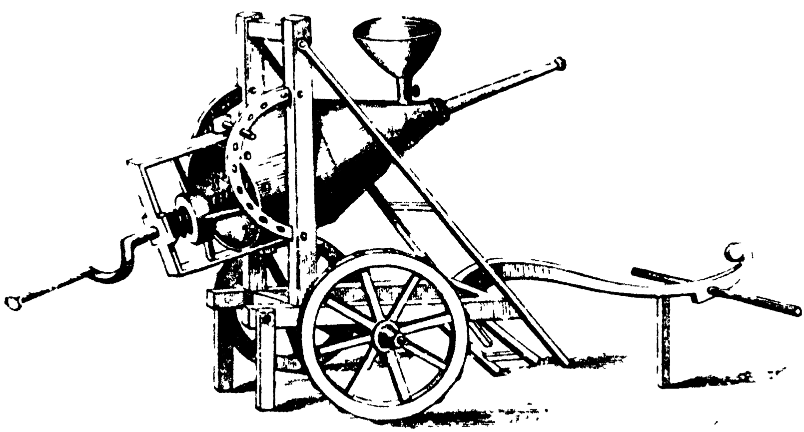


Fig. 143.—Lucar's Engine.

cylinder was retained in the correct position by a bar passing through holes in a pair of transome plates secured to the frame of the carriage. In a book published in 1615 a German pump is described by De Caus (see Fig. 144) which was transported upon a sledge. He claimed that a number were in use in Germany, and that four or five men could work upon the lever or long handle, thus projecting a jet 40 feet in height. He further stated that the working of the pump was easily understood. There are two suckers or valves in the pumps, the lower one opening when the lever is raised and closing upon the down stroke, when the upper one opens to allow the water to enter the branch pipe, which he stated could be turned in the direction of the fire. Why such an awkward kink should be shown in the branch one cannot say, unless it is supposed to denote a swivel joint. This pump was not provided with an air vessel, and the water was poured into the open top of the cask from buckets. At some period before 1675 a great stride was made in the construction of force pumps by the re-introduction of the air vessel.

Fig. 145 is from "The Mysteries of Nature and Art," by John Bate, 3rd edition published in 1654, with the following:—

"The description of an engine to force water up to a high place; very useful for to quench fire amongst buildings. Let there be a brass Barrell

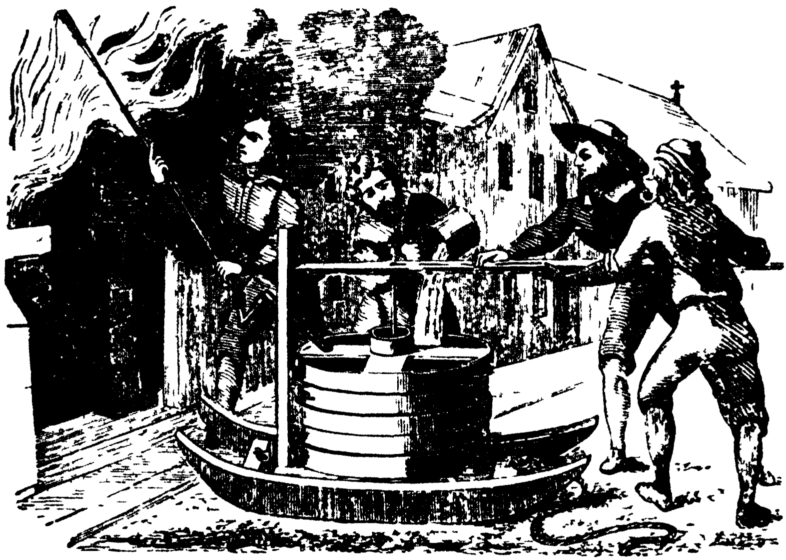


Fig. 144.—German Fire Engine from De Caus, 1615.

provided, having two suckers in the bottom of it: let it also have a sucker nigh unto the top of it, and above the sucker a hollow round ball, having a pipe at the top of it made to screw another pipe upon it to direct the water to any place. Then fit a Forcer unto the Barrell with a handle fastened unto the top: at the upper end of this Forcer drive a strong screw, and at

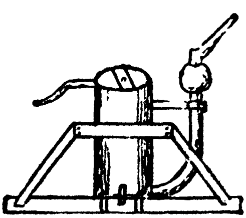


Fig. 145.

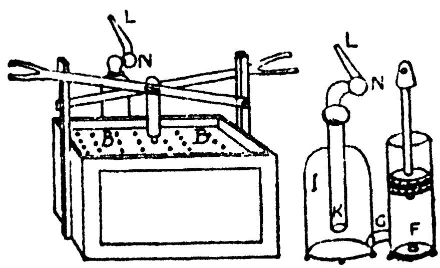


Fig. 146.—View and Section of a Fire Engine with Air Vessel, A.D. 1656.

the lower end a screw Nut, at the bottom of the Barrell fasten a screw, and at the Bar that goeth crosse the top of the Barrell, let there be another screw Nut: put them all in order, and fasten the hole to a good strong frame, that it may stand steddy, and it is done. When you use it, either place it

in the water, or over a Kennell, and drive the water up to it, and by moving the handle to and fro, it will cast the water with mighty force up to any place you direct it."

Fig. 146 shows one constructed about 1656. The tank was made of copper, and the top being a short distance below the top of the sides acted as a tray into which the water was poured from buckets. This top was perforated with holes so that the water fell into the body of the tank in which was placed the barrel and plunger. The air vessel was fixed at the side of the tank and connected by a pipe to the barrel of the pump. From the top of the air vessel was fixed a goose-neck and jet pipe upon a ball and socket joint. Both the barrel and air vessel were raised slightly above the floor by small metal balls or feet. An anonymous communication was made

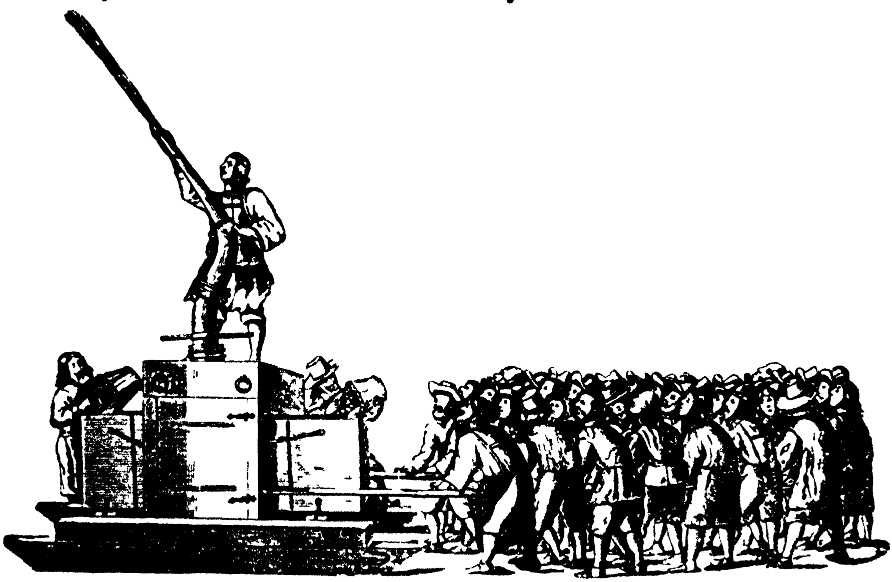


Fig. 147.

to the *Journal des Scavans* in 1675 fully describing this engine as that of Hautsch of Nuremberg. Hautsch had up to that time kept the design and construction of the engine a great secret. It may be that the tray mentioned above was used more as a blind to the inquisitive than as a strainer for the water. A writer named Schotters states that he saw at work in Nuremberg in 1655 a pump (see Fig. 147) constructed by John Hautsch. The case containing the pump was 8 feet (2·44 m.) long, 2 feet (0·61 m.) wide, and 4 feet (1·22 m.) in depth, and was conveyed from place to place upon a sledge 10 feet (3·05 m.) in length and 4 feet (1·22 m.) wide, and drawn by two horses. The levers were so arranged that 28 men could work upon them. Hautsch refused to allow anyone to examine the interior. At the demonstration it was stated that a jet of water 1 inch (0·025 m.) in diameter was thrown to a height of from 80 to 100 feet (24 to 30·5 m.).

Schotters also stated that he did not consider the pump a new invention,

as similar ones were in use in other places, and even his own town of Konigshofen had a small one.

Fig. 148 shows a pump of similar design at Ypres, and seems to have been worked by men pulling levers backwards and forwards.

Hautsch also endeavoured to construct flying machines. The subject of flight was popular with the Nuremberg mechanics, who for generations were noted for their ingenious inventions. From *Philosophical Transactions* 679 (1675) Hautsch's pump would seem much the same as those now to be seen in the crypt at Mont St. Michael.

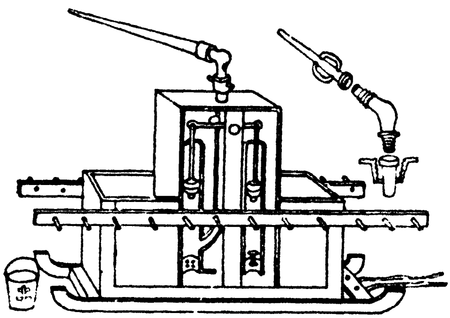


Fig. 148.—Fire Engine at Ypres, A.D. 1739.

During the hundred years following Hautsch's engine, which had been fitted with an air chamber, simple direct-acting pumps without this necessary appliance continued to be used in most of the cities in Europe, and were thus described by French writers in the early part of the eighteenth century.

Fig. 149 shows a pump known as the Strasbourg Engine (A.D. 1739). Near the fore end of the box or tank in which the barrels were fixed, and

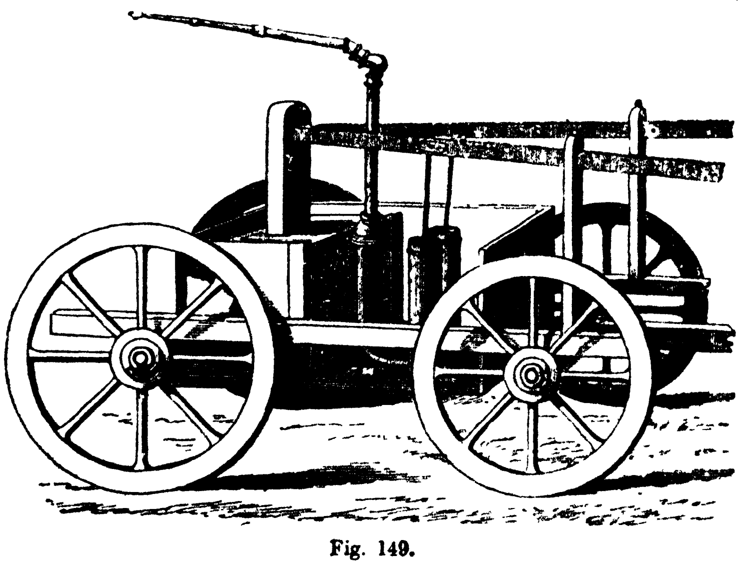


Fig. 149.

across the box was a board with many holes, which acted as a strainer to keep any refuse that might be brought with the water from entering the valves. The pump barrels were 4 inches (0·12 m.) in diameter, with a stroke of 10 inches (0·25 m.). Each of the two pumps could be worked

separately, but only a small number of men could find room upon each lever. The only way in which anything like a jet could be obtained without an air chamber was to work the levers up and down alternately, keeping proper time.

The experience gained in the construction of pumps in the German

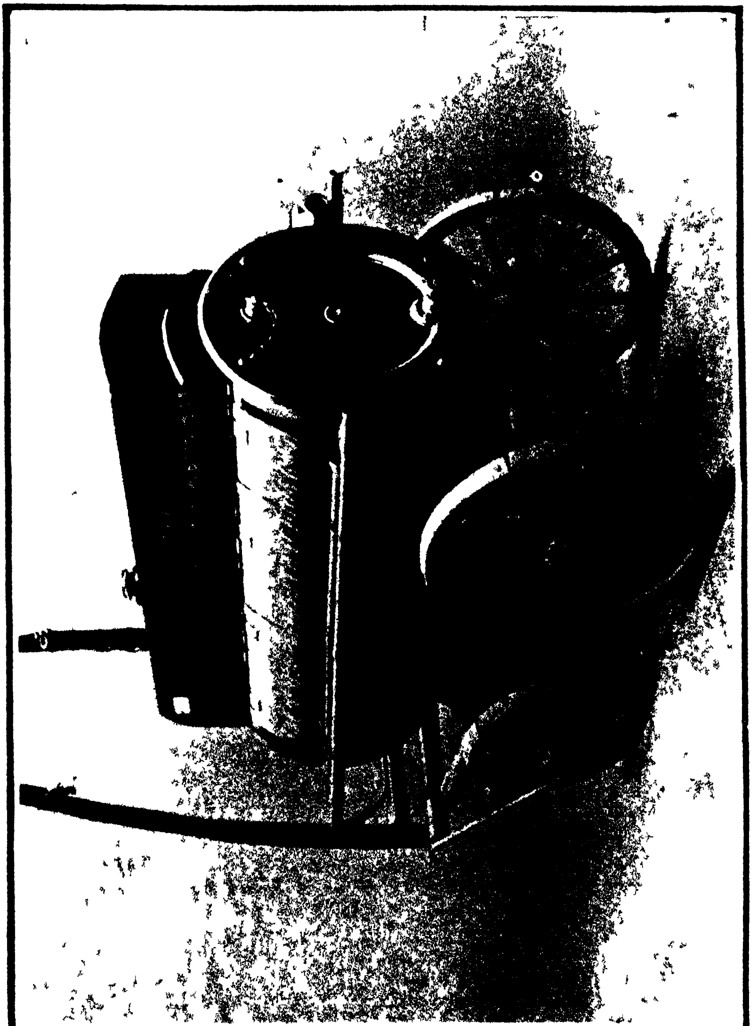


Fig 150 —Fire Engine named "Ye Deluge"

Said to have been used at the Great Fire of London, 1666, and "attended the first fire at Bournemouth."—DR FALLS, 1867

cities does not seem to have reached England until the art of printing became more general, when descriptions of useful appliances would doubtless find their way into neighbouring countries.

Fig. 150 shows a cylindrical apparatus, into the body of which water was poured, and by means of a pump the water was forced through a straight

Fig. 151.—View of Keeling's Engine, with Handles complete (from Dunstable).

nozzle, screwed on to the hinder end. This is an intermediate type between the squirt and the engine proper. This example has evidently been restored and added to, and is apparently a late example of an early type. One at Christchurch is 5 feet 9 inches (1·753 m.) × 8 feet 4 inches (2·54 m.) × 4 feet 2 inches (1·27 m.). Spoked wheels, 2 feet (0·61 m.) and 2 feet 9 inches (0·84 m.) in diameter. Shafts are provided for a horse. A similar apparatus is at Dorrington Castle, Leicester, the size being 5 feet 6 inches (1·68 m.) × 9 feet 4 inches (2·85 m.) × 3 feet 8 inches (1·12 m.), fitted with 24-inch (0·61 m.) spoked wheels and only a drag handle.

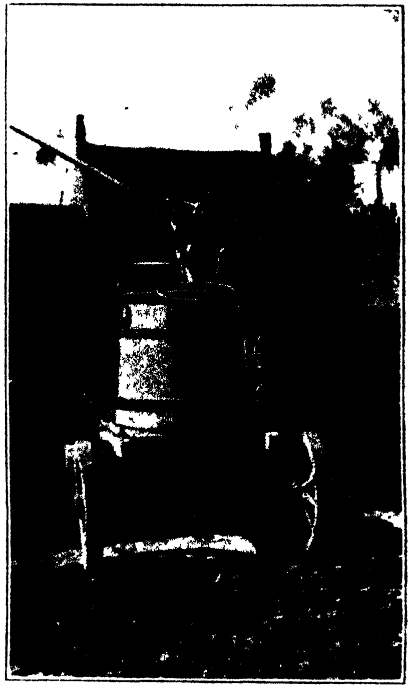


Fig. 152.

Fig. 151 is of an old Manual Engine from Dunstable 6 feet 6 inches (1·98 m.) × 10 feet 2 inches (3·1 m.) × 3 feet 6 inches (1·07 m.). Size of oval tub, 4 feet (1·22 m.) × 3 feet (0·9 m.). Spoked wheels, 2 feet 5 inches (0·73 m.) in diameter. Drawn by hand, and presumably constructed by Keeling of Blackfriars.

Figs. 152 and 153 show a similar pump that was at the town of Damm, near Bruges, Belgium, in June, 1914.

Fig. 153.

Fig. 154 is of a small Manual Engine said to have been supplied to Exeter in 1626, which could be worked by two men, and was carried from the Guildhall to the fire by means of hand-poles and shoulder straps, similar to a sedan chair, and supplied with water from the conduits by means of leathern

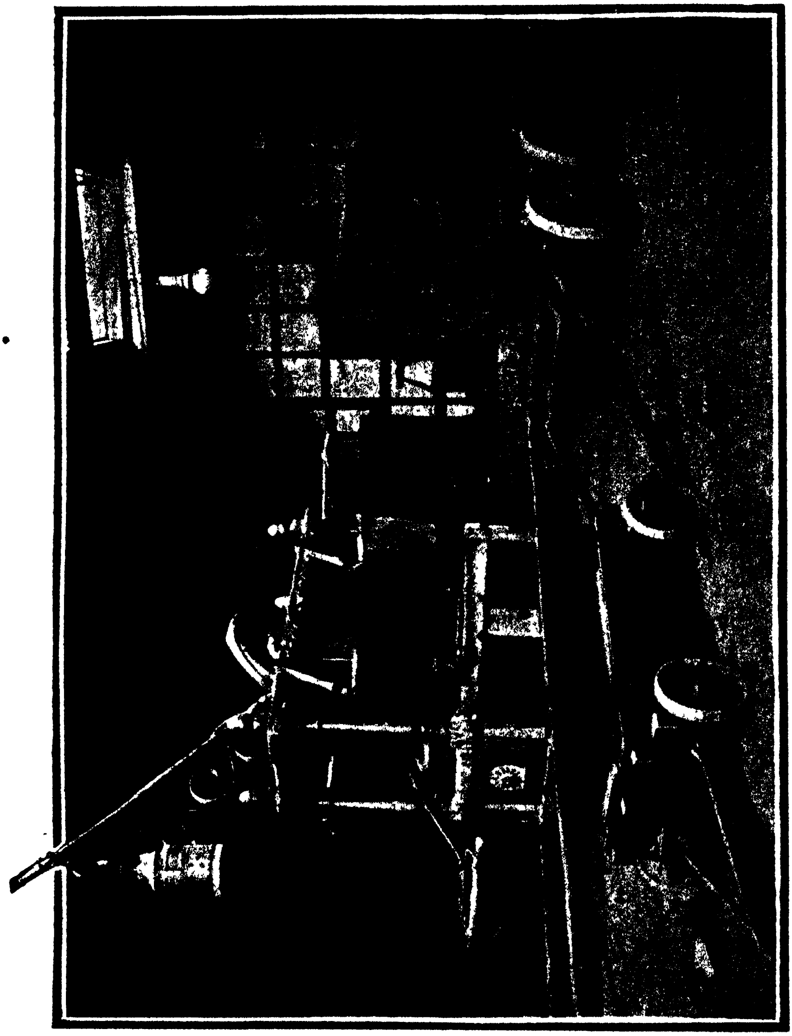


Fig. 154.—Manual Fire Engine used at Exeter, dated 1626.

buckets. The trolley upon which it now rests was supplied at a much later date.

The early types of fire engines in England had the handles for pumping placed endwise. The water was forced up the centre of the apparatus to the branch or play pipe. About the end of the seventeenth century the levers were changed to the sides to allow room for more men at the pumps.

Fig. 155 is the old Grantham engine.

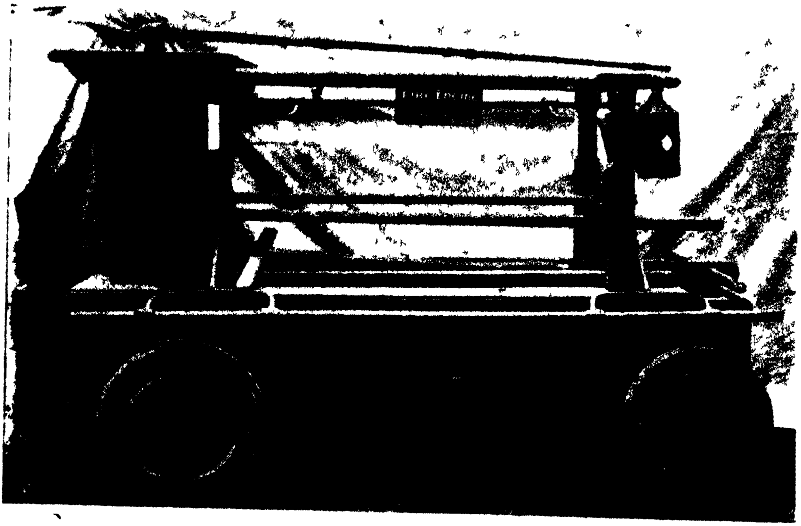


Fig. 155 —Old Newsham Engine from Grantham Date, 1792

Fig. 156.—Photo. by S. G. Gamble, 1878.

Fig. 156 is the same at work in 1878, showing the men upon the treadles and the play pipe being directed by the man upon the platform.

Fig. 157 shows the Market Deeping engine in its waggon, explaining the way in which the Newsham engines were transported.

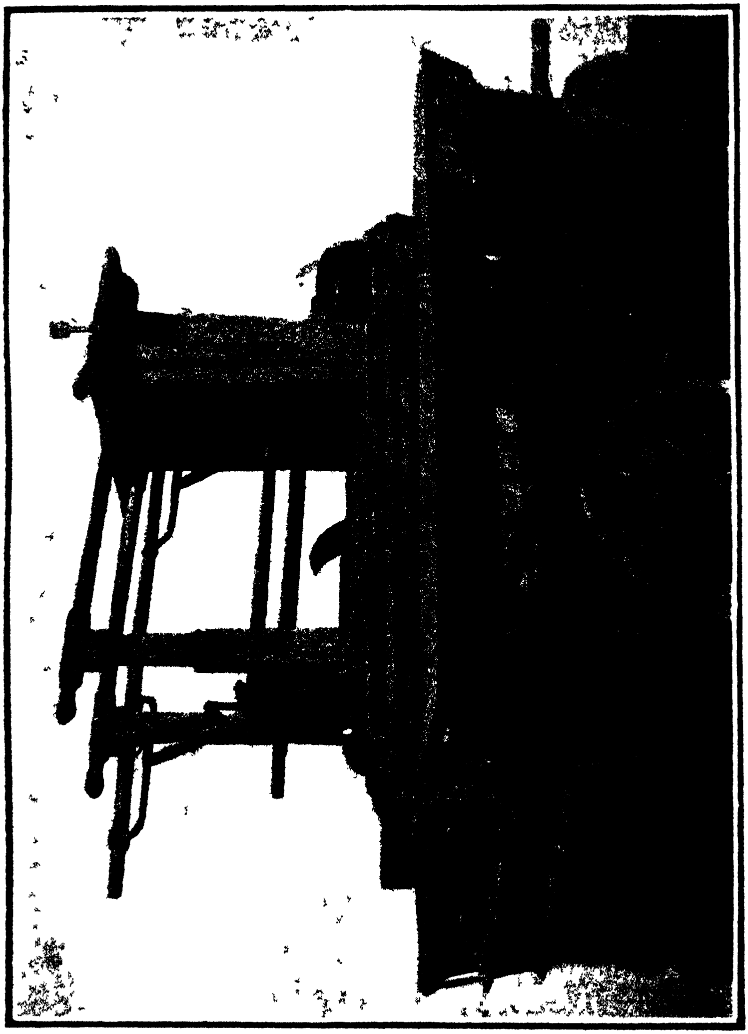


Fig. 157.—Old Fire Engine from Market Deeping

Fig. 158 is an engine from Windsor Castle worked by a crank handle assisted by a flywheel. Height with air vessel, 5 feet 4 inches (1·63 m.); solid 11-inch (0·28 m.) wheels.

Fig. 159. From Towcester, 5 feet 3 inches (1·6 m.) × 3 feet 4 inches (1·02 m.) × 3 feet (0·9 m.), on four 24-inch (0·6 m.) spoked wheels.

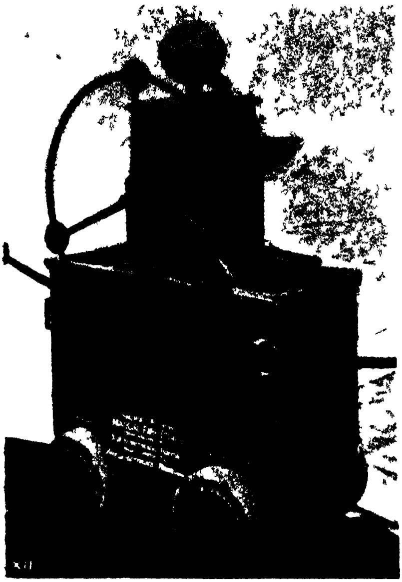


Fig. 158.—Old Engine from Windsor Castle. *With Flywheel.*

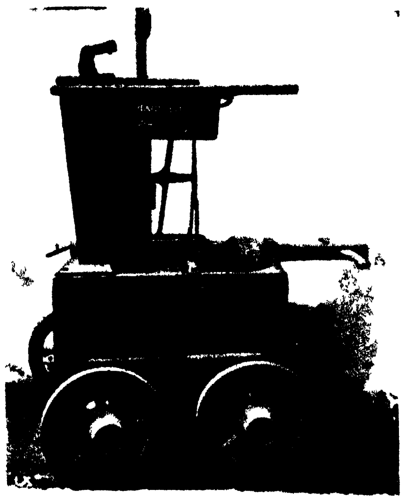


Fig. 159.—Old Engine from Towcester.

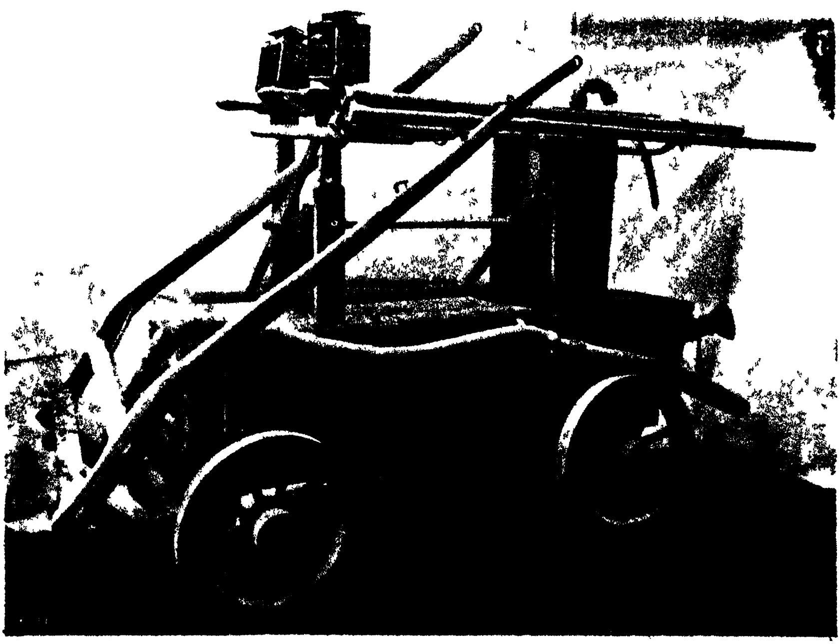


Fig. 160.—Old Engine from Grimsby.

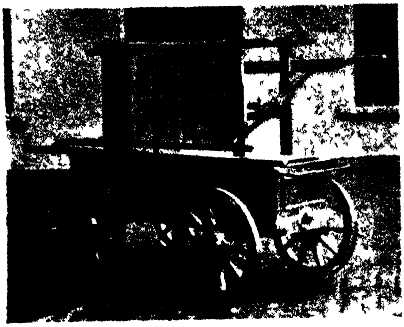


Fig. 161.—Old Engine.

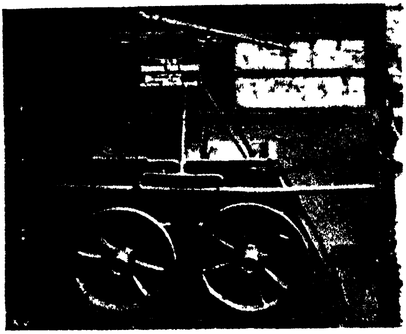


Fig. 162 —Old Engine from Hereford.

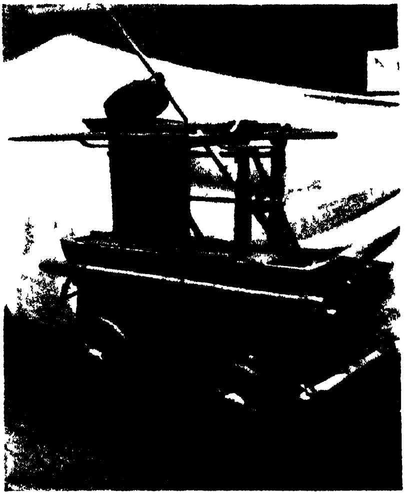


Fig. 163.—Old Engine from Exeter.

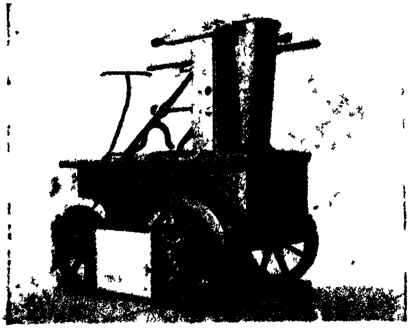


Fig. 164.—Tilley's Engine 1848.

Fig. 165.—Newgate Street Engine.

Fig. 160. From Great Grimsby, 5 feet 9 inches (1·75 m.) × 10 feet 3 inches (3·12 m.) × 3 feet 7 inches (1·1 m.), on four 24-inch (0·61 m.) spoked wheels and fitted with a pair of shafts.

Fig. 161. Old engine without fore carriage, with coupling for suction.

Fig. 162. From City of Hereford, 5 feet (1·5 m.) × 4 feet (1·2 m.) × 2 feet 10 inches (0·86 m.), 22-inch (0·56 m.) spoked wheels.

Fig. 163. From City of Exeter dated 1720, 6 feet (1·83 m.) × 7 feet (2·13 m.) × 3 feet 2 inches (0·96 m.), with fore carriage, wheels 23 inches (0·58 m.) and 17 inches (0·43 m.), with fittings for carrying firemen's torches.

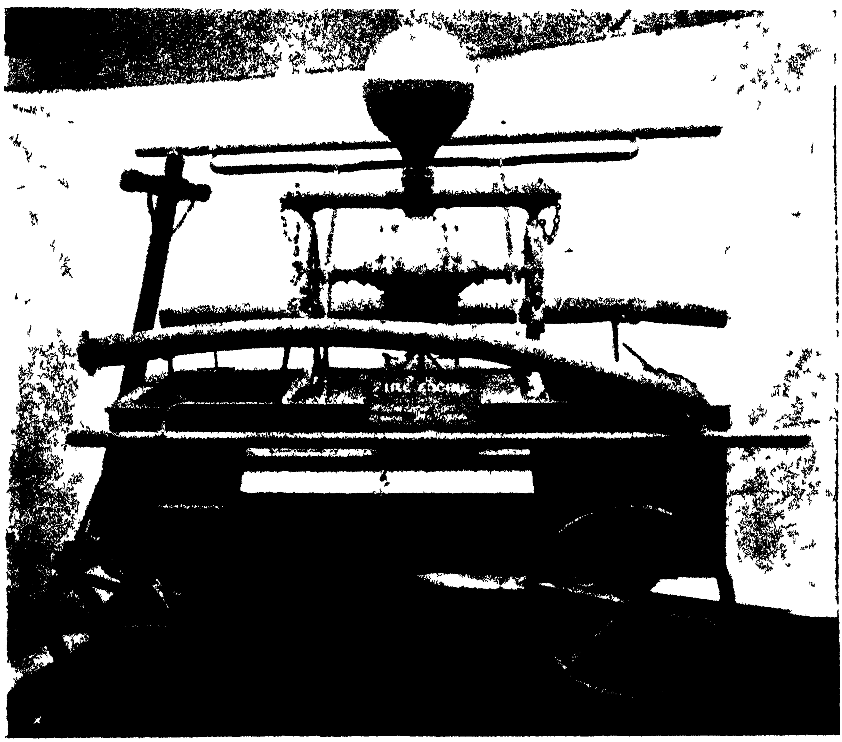


Fig. 166.—Old Engine from Weston Super Mare. (*Roundtree's Type.*)

Fig. 164. Built 1848 for London Assurance Corporation, 3 feet 10 inches (1·17 m.) × 3 feet 8 inches (1·12 m.) × 2 feet 6 inches (0·76 m.), spoked wheels 16 inches (0·41 m.) and 18 inches (0·46 m.), with fore carriage.

Fig. 165. Was built as late as 1852 for the parish of Christchurch, Newgate Street, London, 5 feet 10 inches (1·78 m.) × 7 feet 2 inches (2·18 m.) × 3 feet 6 inches (1·07 m.), with fore-carriage and wheels 27 inches (0·69 m.) and 24 inches (0·61 m.).

Fig. 166. Twenty-man Manual Semi-Rotary Engine, 1799. Roundtree's pattern, with delivery at each end, 6 feet 6 inches (1·98 m.) × 7 feet 2 inches (2·18 m.) × 2 feet 5 inches (0·74 m.), iron-spoked wheels 23 inches (0·58 m.)

and 17 inches (0·43 m); air vessel on top. A few of these engines still exist.

The brothers Jan and Nicolaas van der Heijden, and other engineers in Holland, were busily engaged at the latter part of the seventeenth century in constructing and perfecting force pumps as fully described in the chapter

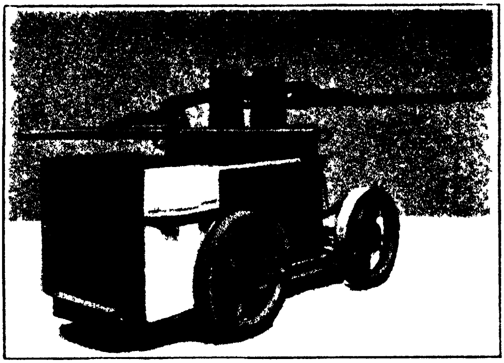


Fig. 167.

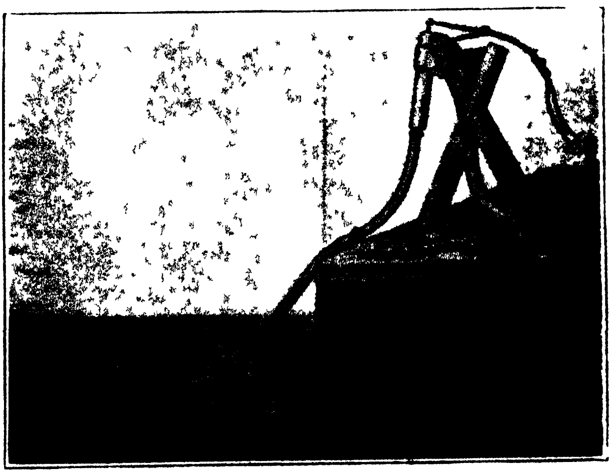


Fig 168

on Hose. About 1672 these brothers introduced the use of leather hose, both for suction and delivery, together with couplings for connecting any number of lengths together. These lengths were supplied with the pumps manufactured by this firm under the name of the "Newly-invented Hose Fire Engines" (see Figs. 167, 168, and 169). In 1676 both brothers were entrusted with the manufacture of the municipal fire extinguishing plant, and also were appointed general Fire Chiefs of Amsterdam.

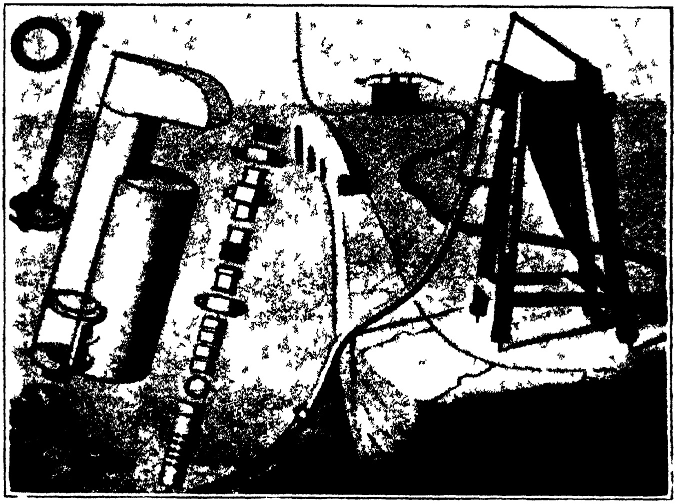


Fig 169

Fig 170 —Portrait of Jan van der Heyden.

Jan van der Heijden (see Fig. 170) died on the 28th of March, 1712, but the control of the Amsterdam Fire Brigade continued in the hands of the Heijden family until 1800.

A very large number of these Hose Fire Engines were made by the firm. Amsterdam alone had sixty, and most of the towns in the Netherlands replaced their old engines with new ones of the improved pattern for the manufacture of which the Van der Heijdens had the exclusive right for twenty-five years from 1677. At the latter part of the seventeenth century fire protection was forced upon the minds of the people of England by the destruction in 1666 of a large portion of the City of London through the terrible conflagration known as the "Great Fire of London," during which 396 acres (about five-sixths of the entire city) were laid waste, 13,000 houses were consumed, and 200,000 out of a population of nearly 500,000 were rendered homeless. The only part of the city proper that was not burned was between the Tower and Coleman Street. Westward of this line to the Temple all was burnt to the ground, including St. Paul's, the Guildhall, the Royal Exchange, 89 Churches, and nearly all the Halls of the City Companies. Acts of Parliament and Orders in Council were passed that had the effect of stimulating the engineers of the country to provide apparatus for applying water with sufficient volume and force "to extinguish fire with greatest effect."

From 1667 Fire Insurance Offices were established, and as their funds increased, more trade in fire appliances followed. This encouraged mechanical engineers to redouble their efforts, with the result that many inventions were produced. The most notable inventions were those of Goodwin Wharton and Bernard Strode in 1676, Nicholas Lewis Maundrell and John Gray in 1712, Richard Newsham (a pearl button maker), William Mason and Thomas Chamflower, 1724, and Fawke of Nightingale Lane, Wapping. Of these, Richard Newsham seems to have produced the most popular machine in the public estimation, and a large number of this type of pump were made (see Figs. 155, 156, 157, 159, 160, 161, 163, and 165).

As a number of Newsham's engines are still to be found in England, an extract from a prospectus issued by him will not be out of place.

"Richard Newsham, of Cloth Fair, London, engineer, makes the most useful, substantial, and convenient engines for quenching fires, which carries continual streams with great force. He hath play'd several of them before his majesty and the nobility at St. James' with so general an approbation that the largest was at the same time ordered for the use of that royal palace. The largest engine will go through a passage about 3 feet wide in complete working order, without taking off or putting on anything, and may be worked with ten men in the said passage. One man can quickly and with ease move the largest size about in the compass it stands in, and is to be play'd without rocking upon any uneven ground with hands and feet, or hands only, which cannot be paralleled by any other sort whatsoever. There is conveniency for above twenty men to apply their full strength, and yet reserve both ends of the cistern clear from incumbrance, that others at the same time may be pouring in water which drains through large copper strainers. The staves that are fixed through the leavers along the sides of the engine for the men to work by, though very light, as alternate motion with quick returns require; yet will not spring and lose time the least: but the staves

of such engines as are wrought at the ends of the cistern, will spring or break if they be of such length as is necessary for a large engine when a

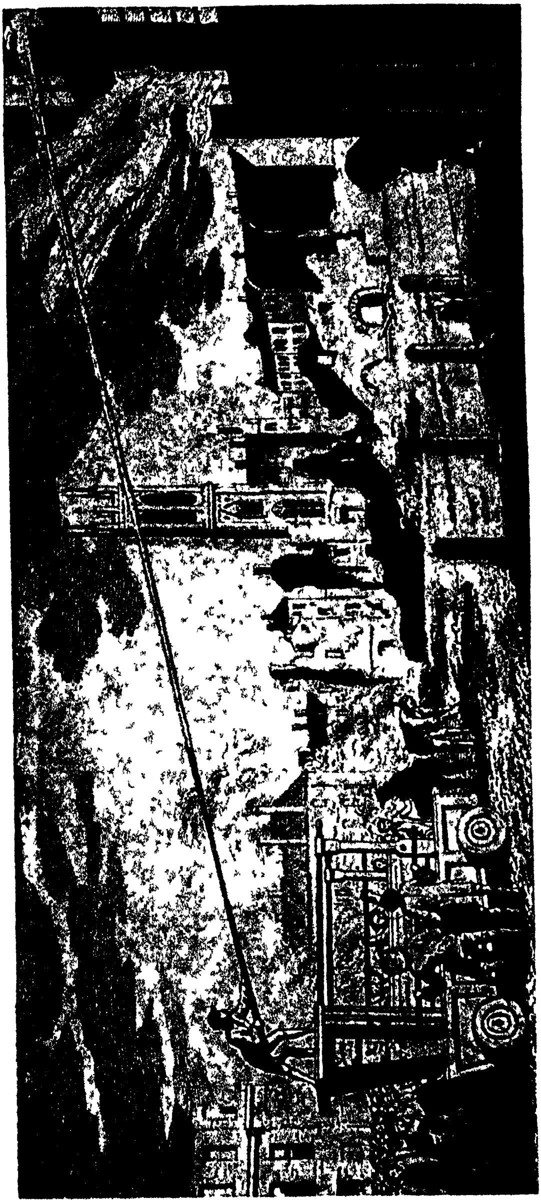


Fig. 171.—Newsham's Engine at the Cornhill Fire, March 25th, 1748.

considerable power is applied; and cannot be fast because they must at all times be taken out before that engine can go through a passage. The

playing two streams at once do neither issue a greater quantity of water, nor is it new, or so useful, there having been of the like sort at the steel yard and other places thirty or forty years; and the water being divided the distance and pace are accordingly lessened thereby.

"Those who pretend to make the forcers work in the barrels with a perpendicular stroke, without racks, wheels, chains, crank, pulley, or the like, by any kind of contrived leavers or circular motion whatsoever, with less friction than if guided and worked by wheel and chains (which of all methods is the best) do only discover their ignorance; they may as reasonably argue that a great weight can be dragged upon a sledge with as little strength as if drawn upon wheels.

"As to the treddles on which the men work with their feet, there is no method so powerful with the like velocity and quickness, and more natural and safe for the men. Great attempts have been made to exceed, but none yet could equal this sort; the fifth size of which hath played above the grasshopper upon the Royal Exchange, which is upwards of 55 yards high, and this in the presence of many thousand spectators.

"Those with the suction feed themselves with water from a canal, pond, well, etc., or out of their own cisterns, by the turn of a cock without interrupting the stream. They are far less liable to disorder, much more durable in all their parts, than any extant, and play off large quantities of water to a great distance, either from the engine or a leather pipe, or pipes of any length required; the screws all fitting each other. This the cumbersome squirting engines, which take up four times more room, cannot perform; neither do they throw one-fourth part of their water on the fire at the like distances, but lose it by the way; nor can they use leather pipe with them to much advantage, whatever necessity there may be for it. The five large sizes go upon wheels well boxed with brass fitted to strong iron axles, and the other is to be carried like a chair."

The claim of Newsham that his engines would project water to the great height of 165 feet (50·29 m.) may have been correct (see Fig. 171), but those whose lot it has been to witness fire engine trials by the Makers will doubt if it was so. The spectators *may* have been surprised at what was accomplished, and those standing near the pump *may*, owing to the angles of view, have accepted the statement of the Makers. The height to them would doubtless appear greater than the actual altitude attained.

Newsham manufactured his engines in six sizes fitted with powerful pumps. The fifth size is given as being able to deliver 160 gallons (726 l.) per minute. They would seem to be the first double-pump engines made in England, fitted with air vessels, side levers, and treadles. Also, they had one great advantage, that when the levers were close to the body of the machine the space required was so small that they would pass through gates or passages 3 feet in width. It must be remembered that in the old provincial towns most of the tradesmen lived at their places of business. The whole of the frontage of the building with the exception of a small side passage was occupied by the shop, the owner living in the back and upper portion of the house. These houses usually had a good yard and garden, and in these yards were situated the wells and rain-water tanks, which were the only water supply of the town. In 1769 a manual fire engine

worked by eight men throwing a jet over 60 feet (18·29 m.) in height was exhibited by a man named Neubert in Hamburg.

It was remarked of Newsham, by a writer in the *London Magazine* for 1752, that in his engines he gave "a nobler present to his country, than if he had added provinces to Great Britain." Desaguliers considered that no part of the engines could be altered for the better, and the general feeling was greatly in favour of them, they being purchased by the various parishes throughout the kingdom, and he received numerous orders for them from

Fig. 172.—Portrait of Hodge, Inventor of the first Steam Fire Engine.

all parts of the world; and it is worthy of note, that the first manual engine used in New York was one of his, and that the first steam fire engine made and used in America was also invented and made by an Englishman, Mr. Paul R. Hodge, C.E. (see Fig. 172).

In 1774 a patent was granted to John Blanch for a pump or engine that would act as an ordinary or force pump, and it was claimed for this that the water could be forced fifty *yards* (45·7 m.) high in a constant stream.

About this time ships pumps were converted by Lieut. Jekyll, R.N., into force pumps, and one so converted, worked by seven men, threw a stream of water 75 feet (22·86 m.) in height and over 100 feet (30·48 m.), in a horizontal direction.

In 1792 Charles Simpkins obtained a patent for the manufacture of metal valves to be used in place of leather, which proved to be a great improvement. They were placed in separate valve chambers, instead of being within the cylinders and air vessels, as had hitherto been the custom. This arrangement allowed the valves to hang at a considerable angle over the openings, with the result that, not only did they open and close with freedom, but their position prevented dirt lodging on the seat and added considerably to the durability of the pumps.

In 1785 and 1793 Joseph Bramah, an engine maker of Piccadilly, obtained patents for a "hydrostatical machine upon a new construction," and claimed that the advantages principally arose from the pistons having their motion round a centre in a rotary direction, instead of reciprocating in a straight barrel. This had the effect of keeping the water in constant motion.

Roundtree, of Great Surrey Street, S.E., in 1799, made semi-rotary engines (see Fig. 166).

Newsham's engine formed the basis upon which improvements were made, which consisted in the main of substituting metal valves for those of leather, the disuse of treadles with their fittings, and the increase of the lateral lever handles beyond the length of the carriage.

Later, the height of the engine was increased and the fore-carriage made of iron, with the transome so arranged that the engine could be turned round in its own length.

In the early part of the nineteenth century, in order to use the town water supply, it was customary to make a hole in the roadway of the street sufficiently deep to act as a basin out of which the water could be drawn. This not only caused considerable disturbance to the highways, but also damage to the valves by the passage of the grit, so that it was found necessary to carry a tub on the tail of each engine into which the water from the fire plugs was conveyed.

Wm. Bradley in 1820 invented a portable canvas dam to take the place of the tubs, but so obstinate were the firemen of that day that it was not until 16 years afterwards that they were generally adopted, and then only owing to the increasing difficulty in breaking up the road surface due to the substitution of stone paving for macadam. Improvements in construction were made in 1864 by Wm. Roberts, of Millwall, who designed the gun-metal side supports with "rule" joints. The long projecting handles, which had gradually been extended to allow more men to pump, were altered in such a way as to project in front when in use and to fold back when in transit, so as not to interfere with the horses. Subsequently the same principle was applied to the projecting rear handles, which rendered the whole machine more compact.

When Braidwood standardised the London Fire Engines, he settled on having the pumps with barrels 7 inches (0·18 m.) in diameter and of 8-inch (0·2 m.) stroke. This was afterwards reduced to 6-inch (0·15 m.) barrels and 8-inch (0·2 m.) stroke, and became known as the London Brigade pattern (see Fig. 173).

The manner of operating a manual fire engine is to run a suction pipe from it into a dam or to connect it to a hydrant. By working the handles up and down the water is drawn through the suction pipe into the pump barrels. It is then forced by the pistons into the air vessel compressing the

air into a smaller compass. There being no escape for the water or air compressed in the vessel except through the pipe connected to the delivery hose, the water is then driven on out of the discharge orifice with a force and range commensurate with the pressure applied to the confined air.

The above-mentioned remarks illustrate the developments of the manual engine operated by levers. This pattern is fitted with two pump barrels, and the volume of water that the engine will deliver obviously depends upon the capacity of these barrels multiplied by the number of strokes made by the piston discharging the water into the air vessel.

The area of a circle is its diameter squared and multiplied by ·7854. This will give an area of 28·274 superficial inches for a barrel 6 inches (0·15 m.)

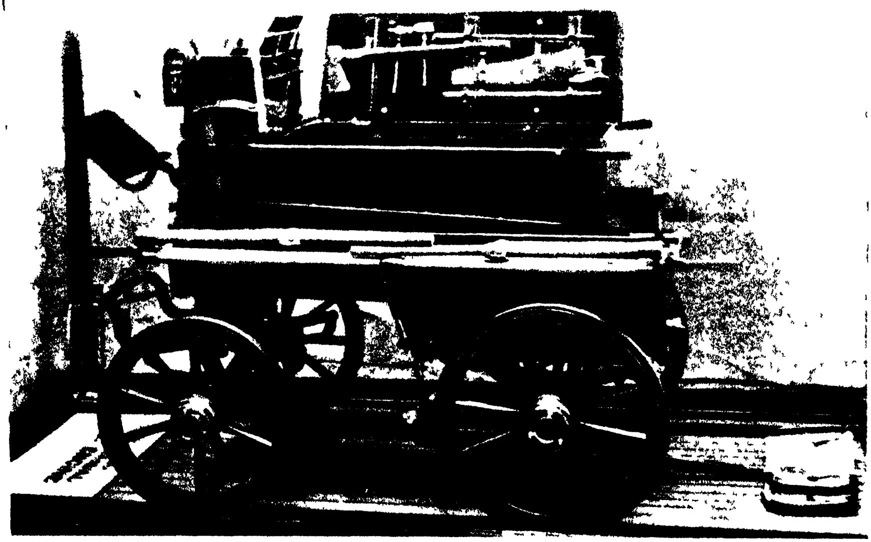


Fig. 173.—Manual Engine of the Metropolitan Fire Brigade.

in diameter, and as the length of the stroke is 8 inches (0·2 m.), it follows that every time the barrel is emptied 28·274 × 8 or 226·192 cubic inches of water is discharged from each barrel, or 452·384 cubic inches for the pair. This = 1·63 gallons (7·4 l.) of water, the number of cubic inches in a gallon being 277·274.

It is possible with a highly trained staff of men to work a manual at the rate of 60 strokes per minute, but it has always been considered that an engine is well manned if an average of 40 strokes per minute, for continuous work, is maintained. Therefore, when a maker claims that the capacity of his pump is so many gallons per minute, it is merely a small problem in arithmetic, the size of the pump being known, to ascertain the quantity the firemen are likely to get out of it. An average of 40 strokes per minute

for a pump of the size mentioned would result in an output of 65·2 or, say, 65 gallons (295 l.) per minute.

From time to time, owing a great deal to competition trials, time-saving devices have been fitted to manual engines, but the fundamental construction of the pumps remains practically the same, with the exception of the addition of an air vessel to the suction to equalise the flow, and an alteration in the position of the outlets. The delivery outlets, originally placed on either side between the wheels, have been brought to the rear, which certainly makes a more compact arrangement, and also allows a certain movement of the appliance (such as sinking the suction deeper, etc.), without unnecessarily running over the hose.

For testing manual, see notes in Appendix.

Steam Fire Engines.—A great deal of prejudice and scepticism attended the advent of the steam fire engine. The earliest productions were by

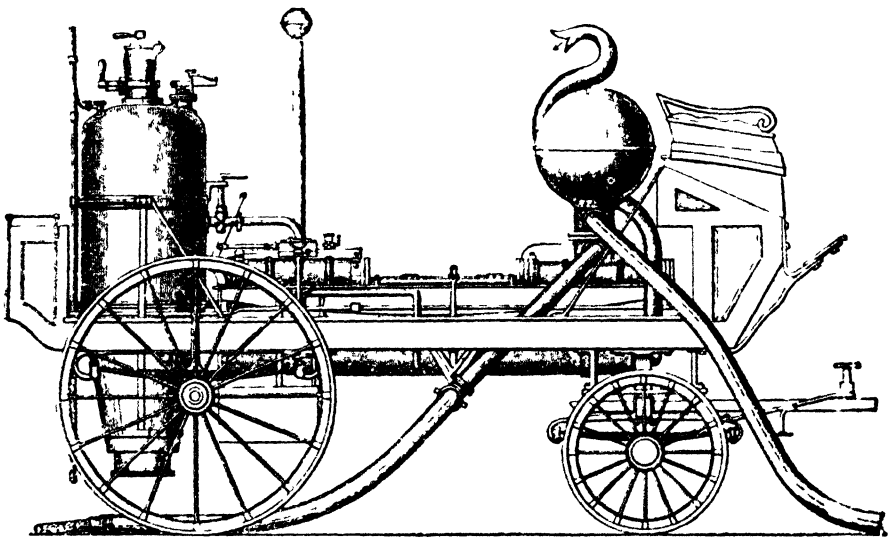


Fig. 174.—Steam Fire Engine, Braithwaite and Ericsson, 1829.

Braithwaite and Ericsson, of London, who, in 1829, constructed five engines (see Fig. 174), but the extension of their use was not encouraged owing, as it was alleged, to the insufficiency of water supply in the streets; and it was contended that until a larger supply could be obtained their use was out of the question; and furthermore, that when a supply adequate for the needs of steam fire engines could be had, a higher pressure could also be given direct from the main without them. No real further development appears to have been made in this country until after the Crimean War, although it is to be noted that Hodge's steam fire engines were in use in America in 1841 (see Figs. 172 and 174*a*).

The difficulty that confronted the engineers of this period appears to have been the evolution of a light boiler that would evaporate a large

quantity of water and yet be sufficiently strong to bear rapid transport from place to place. The two types of boilers which came to the front were :—

(a) Horizontal slightly inclined water tube.

(b) Vertical or suspended tube type in which a tube within a tube is used (see Fig. 175).

The International Exhibition held in London in 1862 brought machinery from all parts of the world to the notice of the general public, amongst which fire engines figured prominently. The trials of fire engines before a jury in Hyde Park on this occasion resulted in an arrangement being made for a second public competitive three-days test to take place at the Crystal Palace on July 1st, 1863.

Ten engines were entered, three of which were made in America and brought over specially for the competition; one of American design made

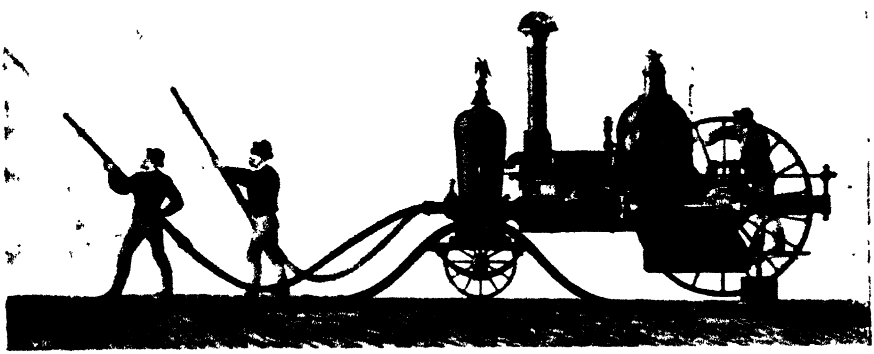


Fig. 174a.—The first Steam Fire Engine, designed by Hodge in 1841.

in England, and the remaining six by English makers. The engines were divided into two classes, the large class, over 30 cwts. (1,524 kg.), and not exceeding 60 cwts. (3,048 kg.) in weight, and the small class under 30 cwts. (1,524 kg.), the prizes being £250 and £100 in each class.

The entries in the large class were :-

"Sutherland" double horizontal cylinders and pumps,	Merryweather.
"Shand" (large) ,, ,,	Shand, Mason & Co.
"Sabrina" ,, ,,	Lee & Larned, U.S.A.
"Victoria" single vertical cylinder and pump,	Amoskeag Co., U.S.A.
"Princess of Wales" ,, ,,	Wm. Roberts.
"Manhattan" ,, ,,	Lee & Larned, U.S.A.
An Engine single horizontal cylinder ,,	Gray & Son.

SMALL CLASS.

1. "Torrent" single horizontal cylinders and pump,	Merryweather.
2. An engine, single vertical ,,	Shand, Mason & Co.
3. "Alexandra" ,, ,,	Amoskeag Co., U.S.A.

These trials were new both to the makers and the committee, and were originated by gentlemen connected with the London Fire Engine Establishment.

The notice published by the committee informed manufacturers that the chief points to which the committee purposed to direct their attention were cost, weight, rapidity in raising steam, facility for drawing water,

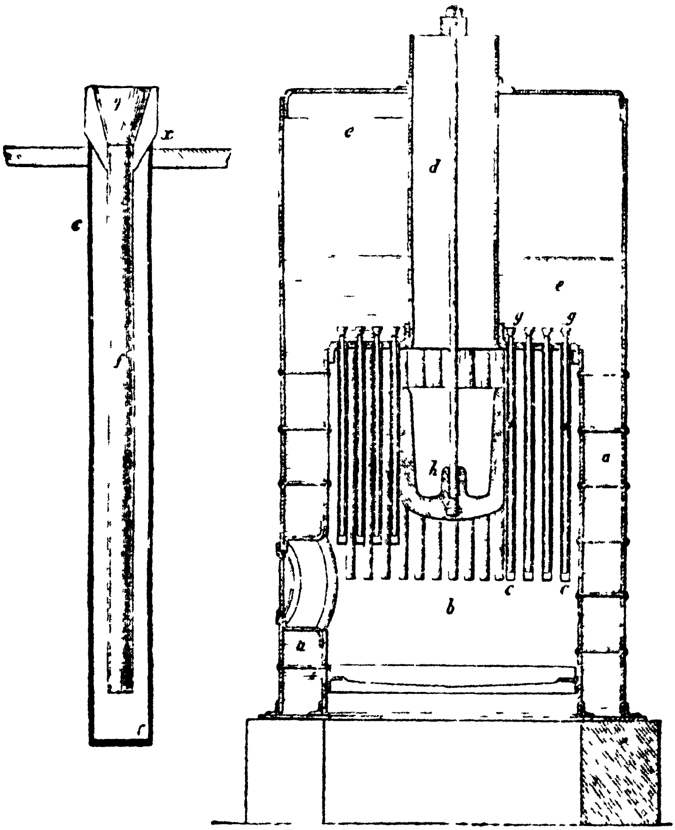


Fig. 175.—Section of Field's Boiler.

volume thrown, distance to which water could be projected with the least amount of loss, simplicity, accessibility, and durability of parts.

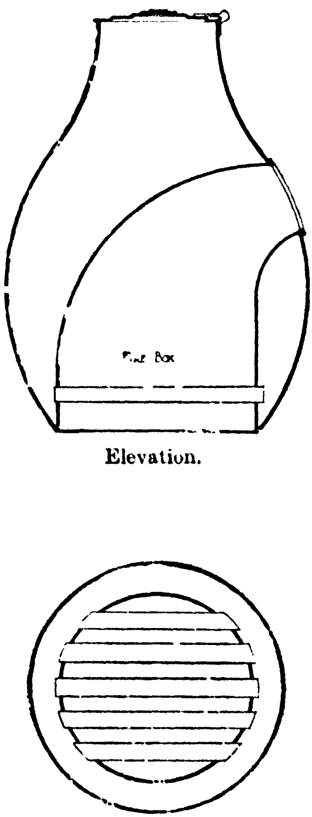
A considerable amount of criticism was raised upon the number of amateurs upon the committee, and the absence of engineers experienced in these kind of fire engines. Several mishaps occurred, and a considerable amount of spectacular demonstration would seem to have taken place, as the *Times* remarked in its account that one engine threw a most magnificent column and maintained the column steadily.

The details of these trials are lengthy, and would not justify the space

they would occupy in this work. The results and awards by the Committee were :—

LARGE ENGINES.

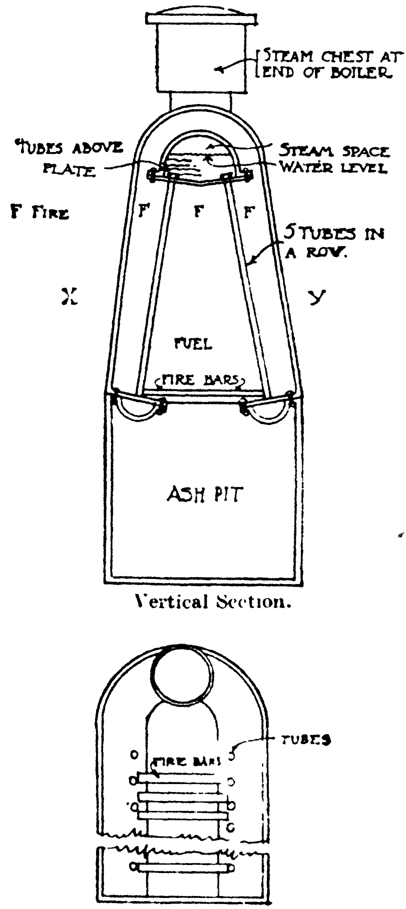
First Prize, £250, "Sutherland,"	Merryweather.
Second Prize, £100, ...	Shand, Mason & Co.
Highly Commended, ...	Wm. Roberts.



Elevation.

Plan.

Fig. 176.—Roman Water-heating Apparatus, Pompeii, A.D. 77.



Vertical Section.

Horizontal Section.

Fig. 177.—Clarke and Mottley's Patent Boiler, 1819.

SMALL ENGINES.

First Prize, ...	Shand, Mason & Co.
Second Prize, ...	Amoskeag Co., U.S.A.

Considering the controversy that took place in the latter part of the nineteenth century on the respective merits of the horizontal and the vertical position of boiler tubes for fire engines, and the claims of the makers, it is

interesting to note that a water heater (Fig. 176) was found at Pompeii dated A.D. 77 which has horizontal tubes. This can be seen at South Kensington Museum. A patent (No. 12,514) was also taken out by Messrs. Clarke and Mottley in 1849 for vertical tubes (Fig. 177).

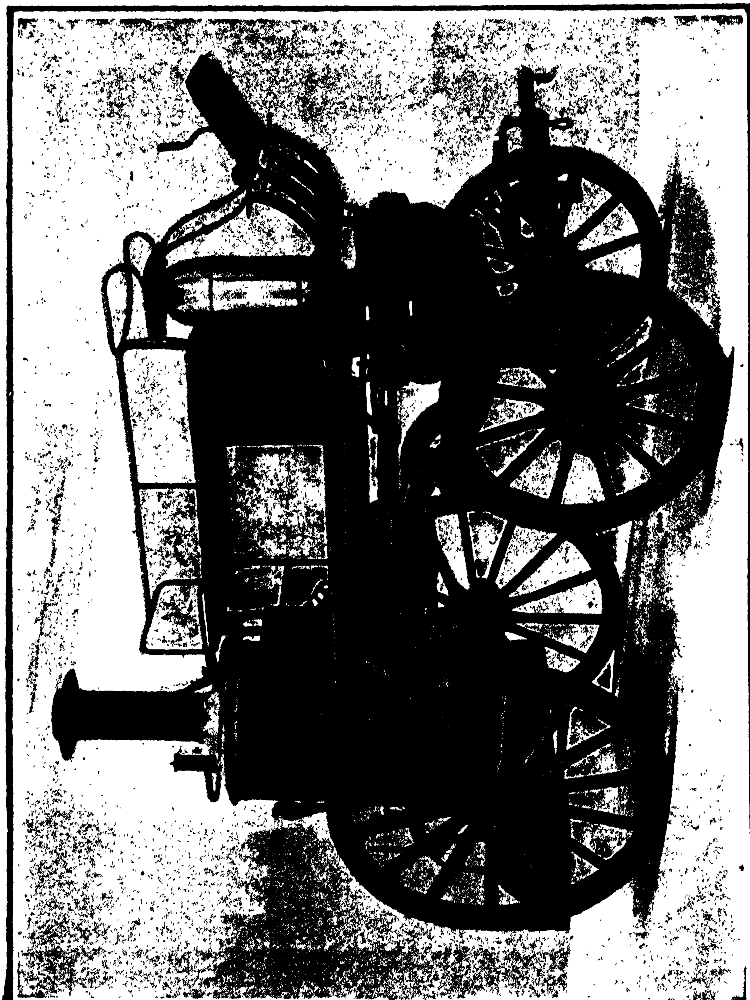


Fig. 178.—The first Provincial Steam Fire Engine (installed at Alton, Hants).

At various times since the trials alluded to above, engineering firms endeavoured to place steam fire engines upon the market, but the demand being small, they could only obtain orders by quoting prices so low that the business was unremunerative. Thus the business, so far as this country is concerned, remained in the hands of Messrs. Merryweather & Sons and Messrs. Shand, Mason & Co.

Fig. 178 shows one of Messrs. Merryweather & Sons early twist bar pattern fire engines.

Fig. 179 shows one of Shand, Mason & Co.'s pattern.

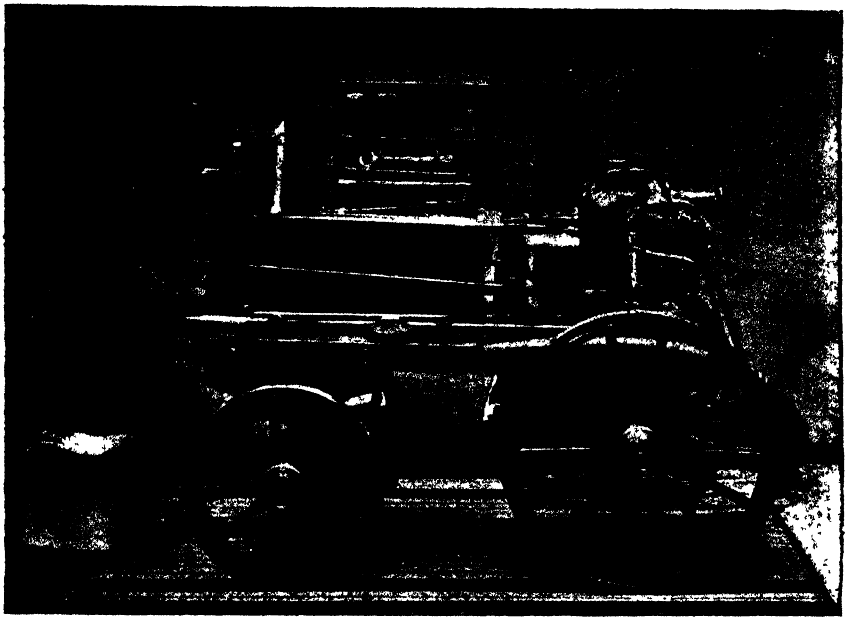


Fig. 179.—Steam Engine of the Metropolitan Fire Brigade.

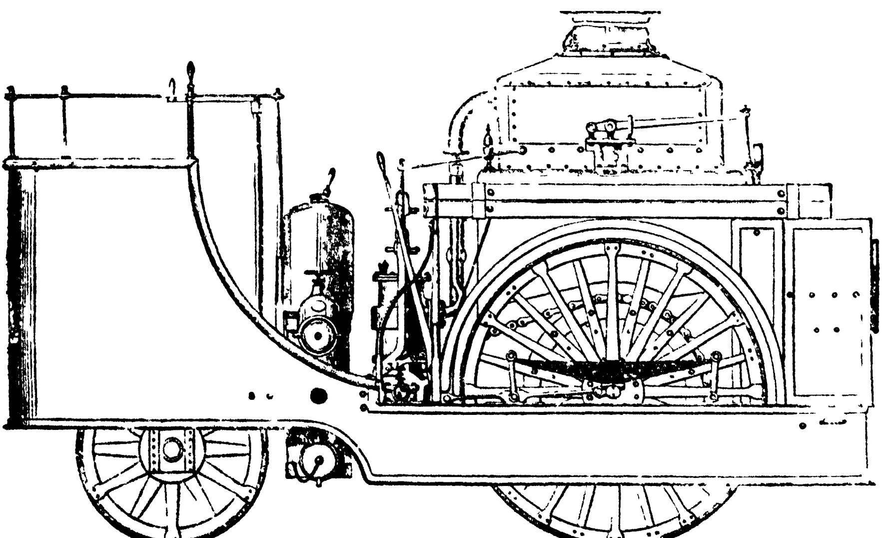


Fig. 180.—Roberts' First Engine (self-propelled), 1862.

Motor Fire Engines.—For generations inventors have striven to produce a satisfactory self-propelled fire engine.

Fig. 180 shows a steam motor built by Wm. Roberts, of Millwall, in 1862. It had three wheels, the front one for steering and the large chain-driven hind ones for driving similar to road rollers. It was 12 feet 6 inches (3·8 m.) long, and 6 feet 4 inches (1·9 m.) wide, and weighed complete with 40 gallons (181 l.) of water just above 7¾ tons (7,874 kg.). This was fitted with a pump and air vessel, hose, etc.; also upon the engine shaft was a pulley to drive fixed machinery. The engine is stated to have a speed of 12 miles (19·3 km.) an hour, and upon a clear road to have attained 18 miles (29 km.) an hour. It is also stated to have negotiated an incline, 1 in 16, a hundred yards (91 m.) long.

In 1902 the London Fire Brigade adapted in their workshops one of their

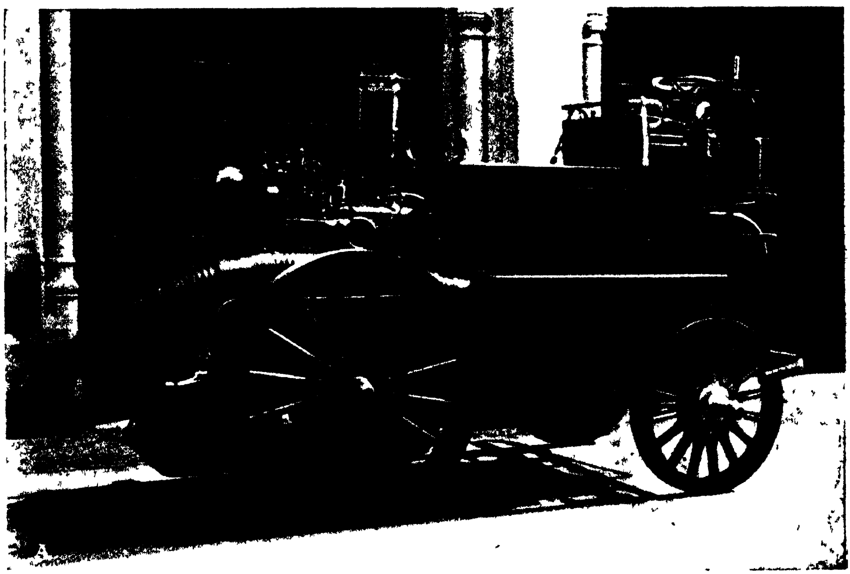


Fig. 181.

horse-drawn 300-gallon (1,362 l.) steam fire engines into a motor (see Figs. 181 and 182); the cost of the alteration was £501, and the original cost of the pump £318. The appliance was for some time used in the inner portion of London upon level roads with fairly satisfactory results, but the boiler, which was only of 47·6 square feet (4·42 m.^{2}), heating surface with 12 gallons (54·5 l.), water capacity, and 6 gallons (27·25 l.) steam space, would not generate sufficient steam to ensure it being relied upon to ascend any considerable gradient without a stoppage being made at the bottom of the incline to allow the necessary head of steam being obtained. This steamer was reconverted to horse traction in June, 1906, after costing £308 for repairs. Ordinary iron tyres were first used on this engine, and these were subsequently replaced by solid rubber tyres.

Fig 182.

Fig. 183.

The next innovation was the purchase in 1903 of a four-cylinder petrol tractor of 24 to 30 horse-power. This was a four-wheeled vehicle (see Fig. 183) to take the place of the fore-carriage of an ordinary horse-drawn engine, and attached thereto by means of a perch bolt. On account of the large proportion of weight being carried on the hind wheels, this form of traction was found to be unreliable, and, in fact, dangerous when descending even moderate gradients, there being a tendency for the steamer's wheels in the rear to skid round broadside on to the tractor itself. The tyres on the tractor were solid rubber. This appliance, which cost £750, ran 3,180 miles, having attended six fires, but only worked at one. It was sold in 1909 for £8 10s., having cost £156 in repairs. The total cost, including all capital charges, petrol, etc., was 5·89 shillings—per mile actually run.

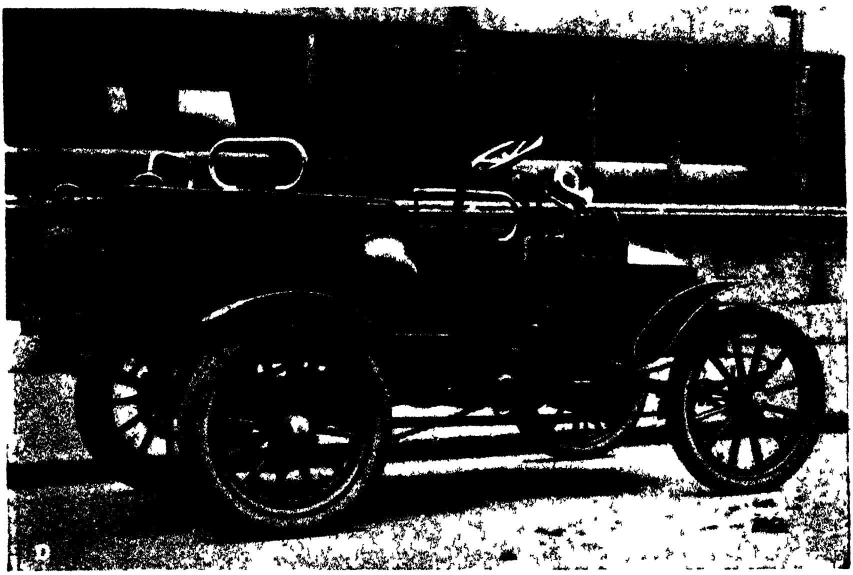


Fig. 184.

In July, 1903, a 10-12 horse-power two-cylinder motor chassis fitted with pneumatic tyres was purchased at a cost of £463, and was converted in the Brigade Workshops at a cost of £93 into an appliance carrying three men, a small pump, and a box containing 500 feet of hose, etc. (see Fig. 184). By means of gearing the pump could be driven from the petrol motor. After the pump had been removed (see Fig. 185), it was successfully used in one of the suburban stations for some years. The petrol consumption of this machine was 1 gallon (4·54 l.) per 8½ miles (13·69 km.), equal to a cost of one-tenth of a shilling per mile for petrol and oil, it ran 15,212 miles (24,481 km.). The total cost, including all capital charges, petrol, etc., was 1·33 shilling per mile run.

In February, 1905, there was purchased, at a cost of £1,130, a 500-gallon (2,270 l.) steam motor fire engine of the "Fire King" type (see Figs. 186

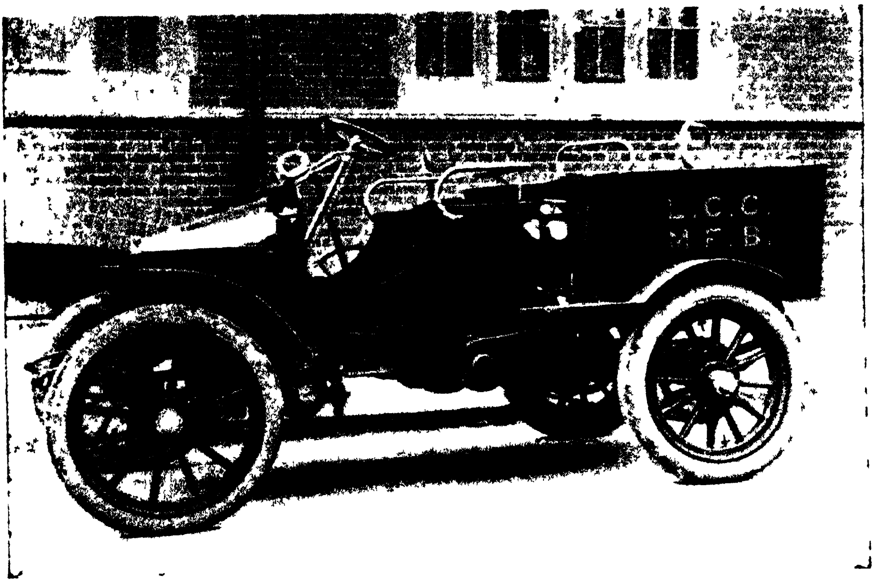


Fig. 185.

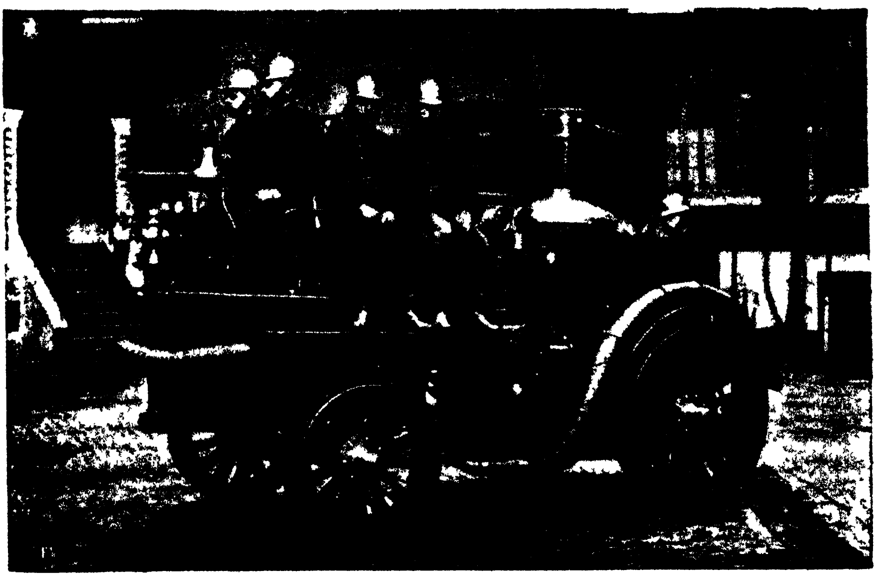


Fig. 186.

and 187), in which the same engine which drives the pump also drives the road wheels by means of a clutch. In the following year others were purchased. These motor steamers when complete with hose, men, etc., weigh about 5¾ tons (5,842 kg.), and were fitted with solid rubber tyres. They carried 80 gallons (363 l.) of reserve water, sufficient at first for 9 miles (14·48 kg.) running, and consumed 2 gallons (9·1 l.) of paraffin per mile (1·6 km.) run. The maximum speed was 25 miles (40·2 km.) per hour on the level. The oil tanks held sufficient supply for the pump to work at full power for two hours. The boiler capacity was 40 gallons (181·6 l.), of which 19 gallons (86·2 l.) steam space and 21 gallons (95·4 l.) water.

Later, smaller engines of 400-gallon (1,816 l.) capacity were purchased at a cost of £977 each. These appliances weighed 4¾ tons (4,826 kg.), and

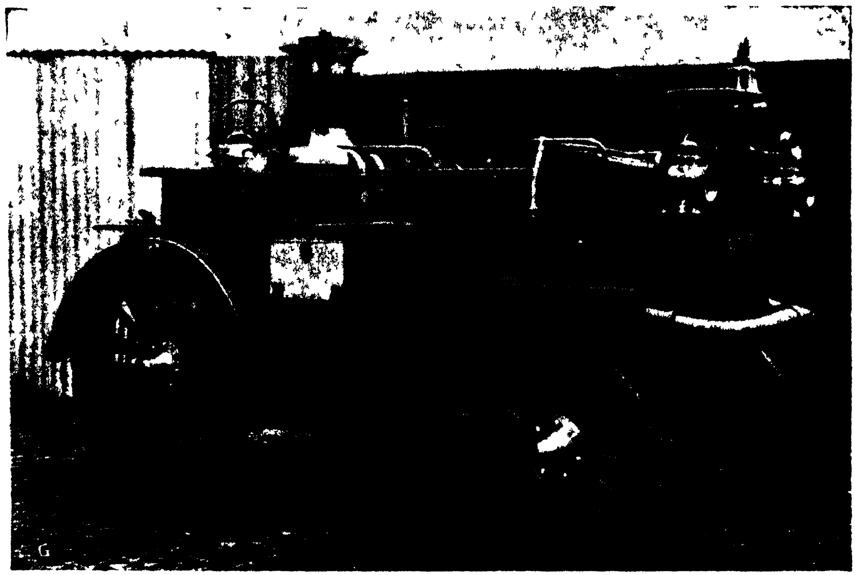


Fig. 187.

with the exception of being generally smaller, were similar in every respect to the larger ones.

To keep a steam pressure of from 80 to 100 lbs. per square inch (5·4 to 6·8 atms.) in these boilers, so as to be ready for a turn-out, required a consumption of 1,350 cubic feet (38 m.^{3}) of coal gas per 24 hours.

The weight of the steam motors caused, when travelling at high speeds, such undue vibration that the pipe joints could not be kept tight, with the result that so much steam was lost that the water supply had to be replenished every few miles, with the consequential loss of valuable time.

In 1906 and 1907 a firm of engineers made an experiment by converting an ordinary horsed steamer to self-propulsion by means of a single-drive front wheel. Steam was led to the cylinders from the boiler at rear by flexible tubing, and passing through a hollow perch bolt. The single driving wheel

in front had a very broad rubber tyre, and was direct driven by two steam cylinders, one on either side, the whole being carried on a cast-steel frame, which took the place of the ordinary fore-carriage, and was turned directly by a large steering wheel on the top of the column. The engine was without side props or foot-brakes. The idea being to use the steam reversing gear as a brake. The drain-cocks attached to the cylinders upon the front wheel could not be operated while the engine was in motion. The steering wheel required both hands to move it, and the motion of the road wheel was too quick in relation to the steering wheel, so it was impossible to steer a fine course. To manipulate the steam regulator and reversing gear (brake) it was necessary to take the risk of having only one hand upon the steering wheel. The experiment, however, was quite unsatisfactory, since—leaving

Fig. 188.

on one side the question of stability, which was by no means good (the engine did actually turn over)—the weight on the front wheel was not sufficient for driving purposes, and when the wheel slipped steering power was also lost.

The expense incurred in repairing the steam motors led to their being superseded by the internal combustion engine.

In 1906 the London Fire Brigade decided to adopt mechanical traction for all new appliances, as by this time automobile construction had reached such a point that it was possible to obtain a machine capable of doing the work required. Appliances (see Figs. 188 and 189) were, therefore, bought and fitted up in an exactly similar manner to a horsed escape—that is to say, to carry five men, a 55-foot (17 m.) telescopic ladder, a first-aid appliance consisting of 60 gallons (272 l.) of water under pressure in a metal tank

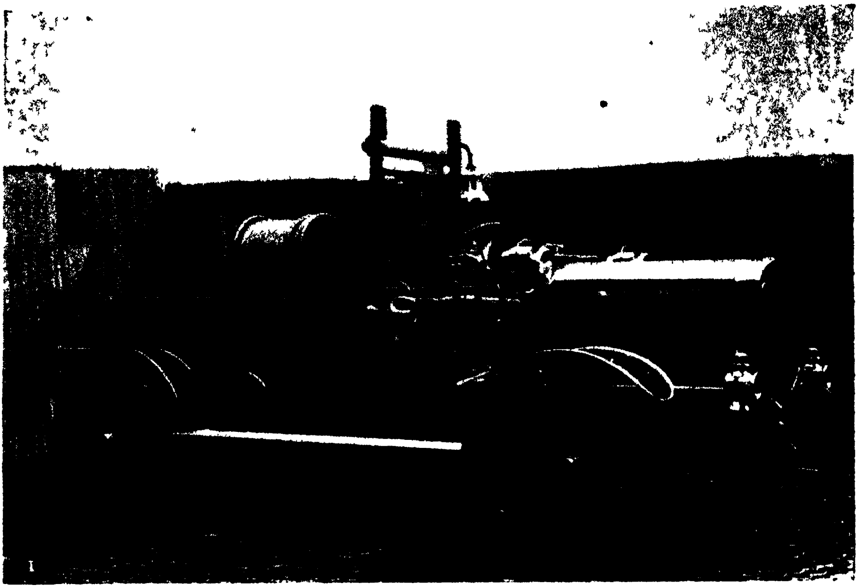


Fig. 189.

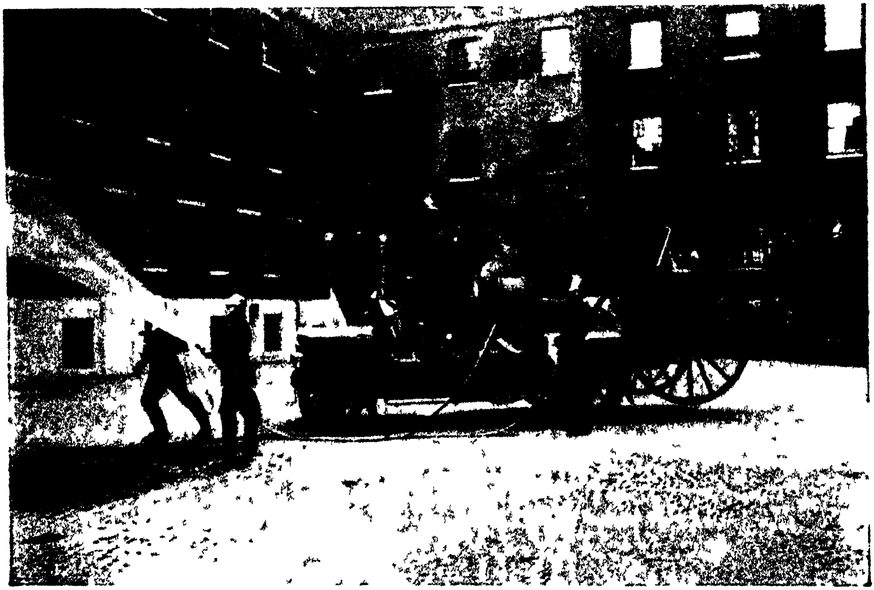


Fig 190.

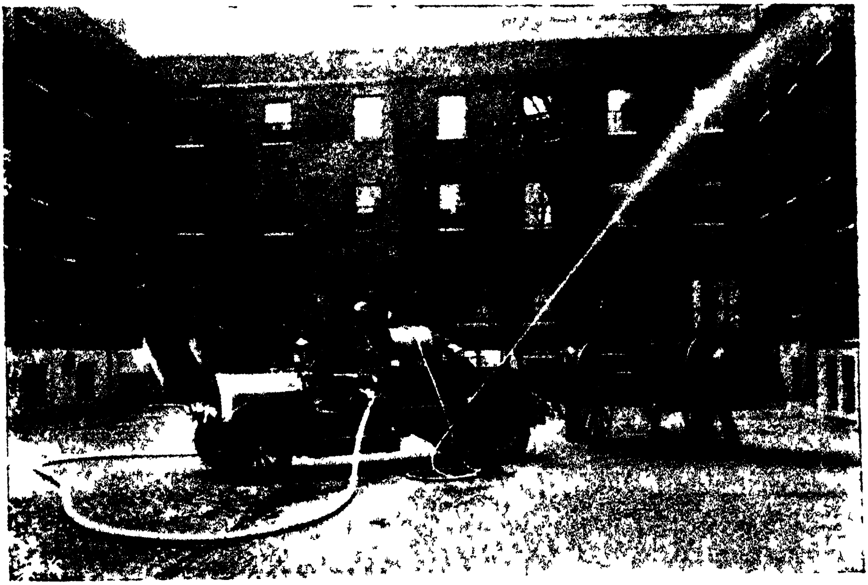


Fig 191.

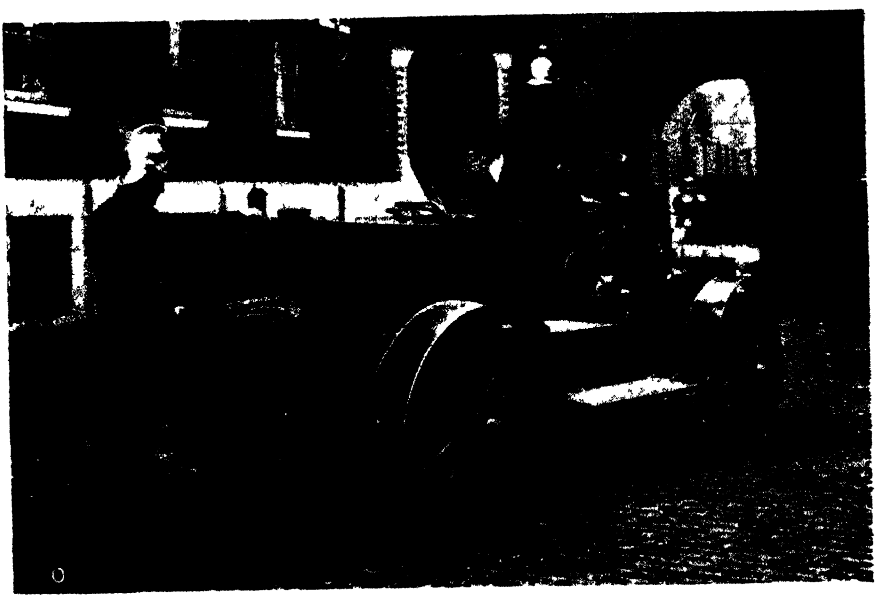


Fig. 192.

with 180 feet (55 m.) of tubing, 500 feet (152 m.) of rubber-lined hose, and the necessary apparatus for connecting up to the street mains. The chassis of this machine is of the type used for motor omnibus or heavy lorry work, fitted with solid rubber tyres, and a four-cylinder engine of 50 horse-power. Experience has shown that 50 horse-power is necessary if a fair speed is required up hills.

The telescopic ladder, which is of the type generally used in the Brigade, is carried on a pivoting cradle at the rear of the machine, by means of which it can be immediately brought to the ground on arriving at a fire. This machine, without ladder, hose, etc., cost £940.

The weight carried on the chassis and body is about 1½ tons (1,524 kg.), including five men, and the total weight of these appliances when fully

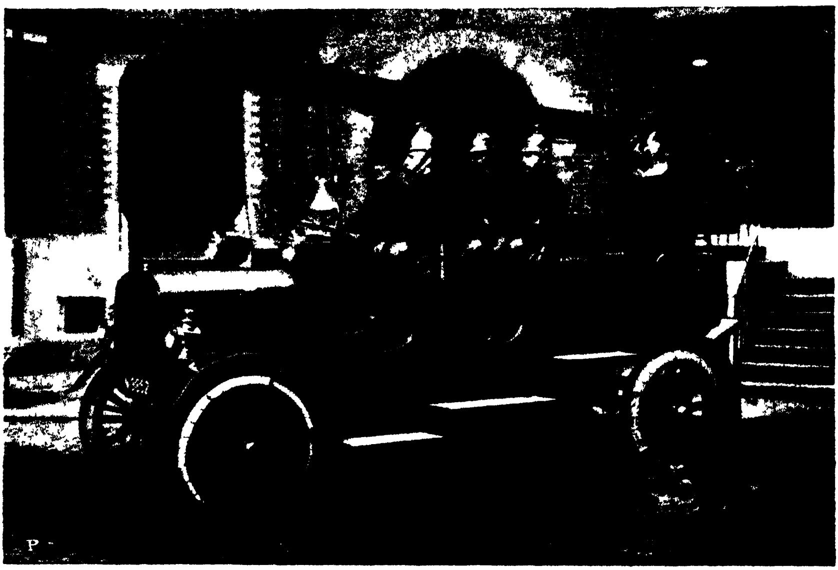


Fig. 193.

loaded is between 4½ (4,572 kg.) and 5 tons (5,080 kg.), varying a little with the type of chassis. Figs. 190, 191, 192, and 193 show chassis of various makes and design, but the same articles are carried, and the general principles of the machines remain precisely the same as in Figs. 188 and 189. Of course, with the improvements in automobile construction which are effected year by year, the cost of running and maintenance decreases considerably.

In February, 1908, internal combustion engines (see Figs. 194 and 195) were used in combination with fire pumps. These appliances have the same chassis as the motor escapes, but instead of a ladder a centrifugal or a three-barrel reciprocating pump is bolted to the frame in the rear of the chassis. All the pumps are fitted with three ignitions, two Bosch magnetos, one being dual. When the appliance is brought to rest, the gears which drive

Fig. 194.

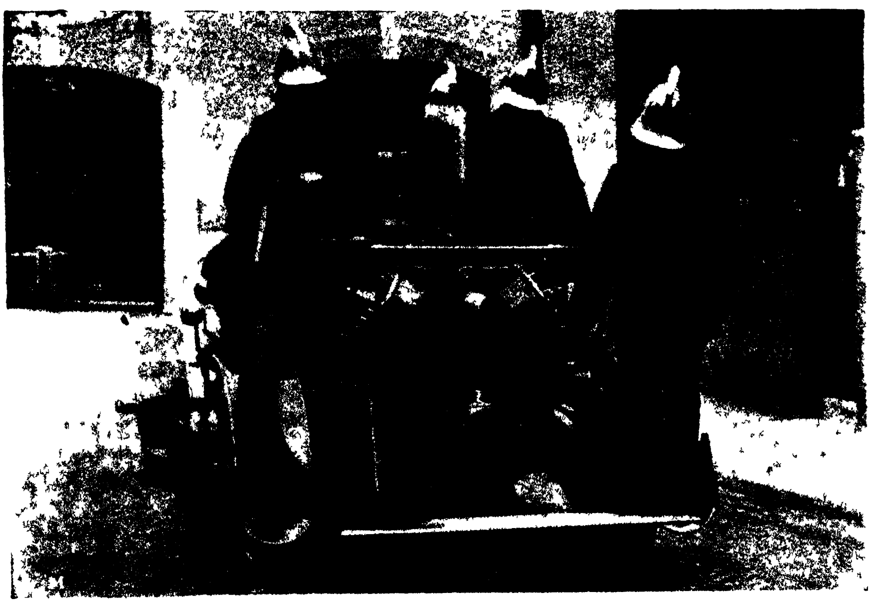


Fig. 195.

it along the road are placed in the neutral position, and the pump can then be driven through helical or spur gearing and a short shaft which connects by means of a dog clutch in the gear box to the propeller shaft from the engine, the normal revolutions per minute being, engine 1,000 and pump 250. As the machine is standing still when pumping, a pipe is led from the main pump to the circulating water system of the engine, in order that it shall not overheat. The capacity of these pumps is 500 gallons (2,270 l.), with open delivery, and 410 gallons (1,862 l.), at 140 lbs. water (9·52 atms.) pressure. They have three delivery outlets, and in some cases under test have been at continuous work pumping without being touched for four hours. The cost of running these machines on the road is approximately the same as

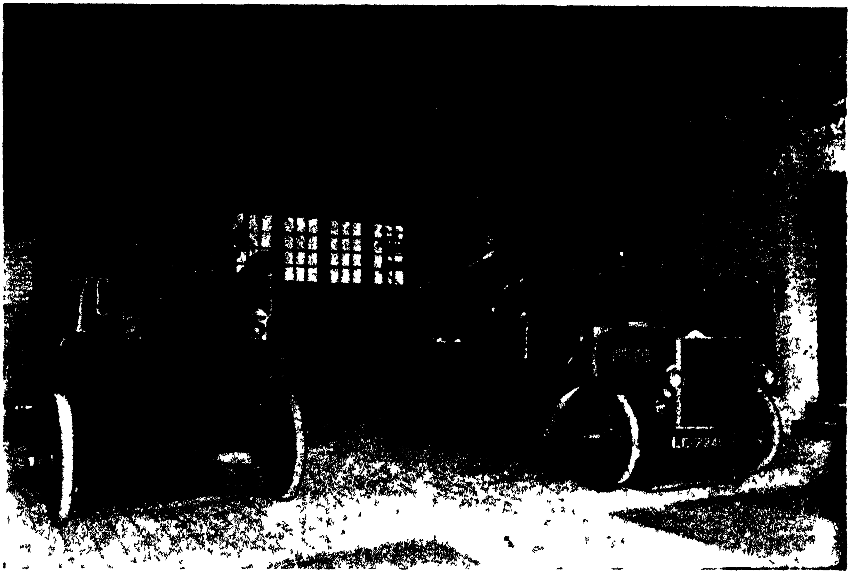


Fig. 196.

for the latest type of motor escape. When pumping they use ·16 gallon (0·71 l.) of petrol per 1,000 gallons (4,541 l.) of water pumped at a pressure of 110 lbs. on square inch (7·5 atms.), lubricating oil, etc., in proportion.

In order that these motor appliances may be kept ready to turn out at a moment's notice, they are started up by the man on watch and run for a few minutes every four hours. In the winter the engine rooms (see Fig. 196) in which the motors stand are kept warmed by means of hot-water radiators. As ignition troubles are, perhaps, the most frequent cause of breakdowns, all motor appliances should be fitted with at least two, and sometimes three, separate and distinct systems of ignition.

The question of the best type of tyre and non-skidding device requires very careful consideration, as many accidents have been caused by appliances skidding.

The reliability of motors increases as the improvements in construction are introduced, and the drivers become more efficient and take greater care. It is difficult to make drivers understand the momentum a 5-ton (5,080 kg.) machine travelling at 20 miles (32 km.) an hour can exert.

The British never seem to have properly grasped the value of electric power, possibly owing to the fact that the abundance of coal in this country has stimulated the development of the steam engine almost to the exclusion of other systems. The cheap supply of electricity in other parts of the world encouraged investors to produce electric motors attached to pumps so arranged that they could be joined up by cables to the local tramway systems, which are to be found running on most of the main roads in continental countries, and run from storage batteries when the current was out of reach. Also they can be used for transporting comparatively light-loaded machines in flat districts.

In England electrically propelled appliances, although possessed of many good points, have not found lasting favour for fire purposes. The heavy load of their indispensable storage batteries, their limited radius of action, especially in hilly districts, the baneful influence of bad roads, the difficulties and expense incurred in maintaining accumulators in efficient working trim when employed under the irregular conditions, inseparable from the Fire Service, all detract from their practical utility. Hills require such an extra consumption of electrical power that there is always the danger of the machine having to be towed home.

The advent of a commercial Petrol Motor into the Fire Service has undoubtedly marked an epoch in the work of fire extinction, since it allows an immediate turn out, a high speed, capability of travelling long distances, and a small cost when not in use.

For fire brigade purposes, a good standard commercial type pattern is best, and it is an advantage if the makers works are near, or a depôt from which spare parts can be obtained. *Remember the Motor is the principal part of the appliance*, and will give most of the trouble. The question as to whether it is coupled to a reciprocating or centrifugal pump is a matter of small moment considering the very small period of time the pumps are at work.

The superstructure or body is a matter for the requirements of the brigade who will use it, and whether an escape or other ladders are carried. In setting out the positions for the various tool boxes, see that there is a place of everything, and then there will be no excuse for tools, etc., being out of their place.

The pumps used in connection with internal combustion engines are the Reciprocating, Rotary, and Centrifugal.

The Reciprocating Pumps for use with motors should not have less than 3 barrels. The Hatfield is one of the most suitable for use in connection with petrol motors. It is compact, having three separate pumps, each complete with plunger, valves, etc., drawing from a common suction chamber and delivering into a common delivery chamber (see Fig. 197). It will be seen each pump occupies one-sixth of the hexagon and is worked from a single crank.

Reciprocating Pumps being direct in action, the quantity of water passed is known by the size of the pump barrel, the length of the stroke, and the

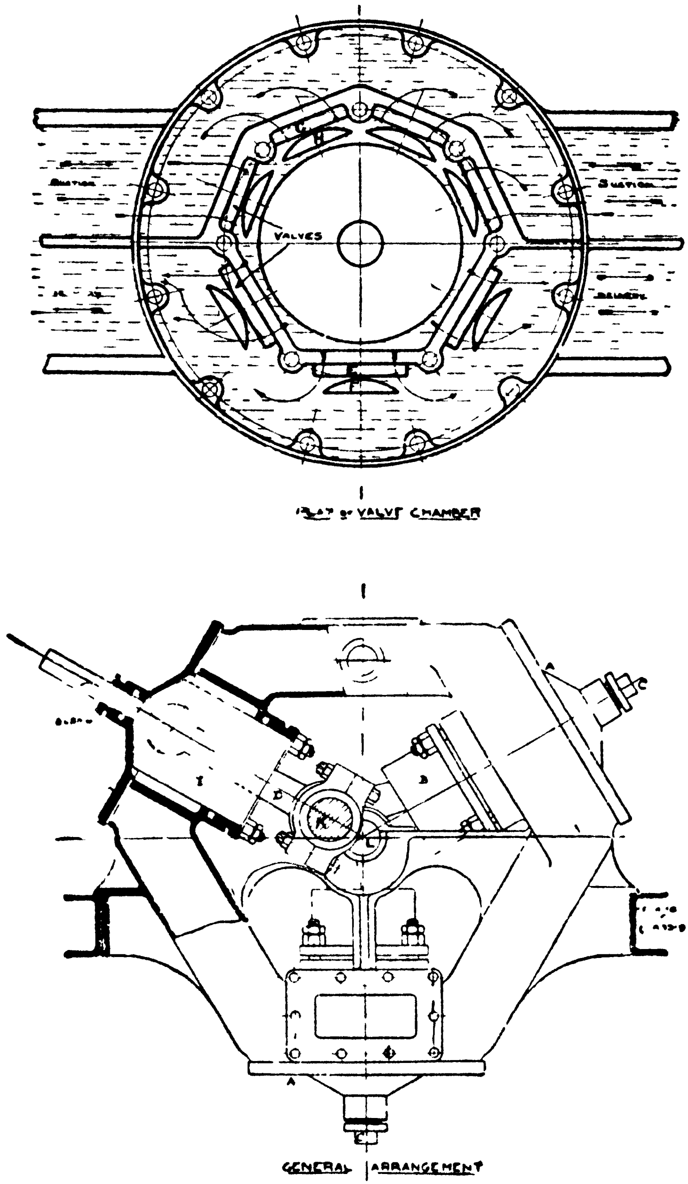


Fig. 197.—Three-throw Reciprocating Pump,

A Pump head.
B Plunger.
C Plunger Guide Rod.
D Connecting Rod.
E Delivery Valve.
F Delivery Valve Guard.
G Suction Valve.
H Suction Valve Guard.
K Crank.
L Crank Shaft.

number of strokes. The slip is small when the pump is in good repair. When the piston is drawn out, the space in the barrel must contain air or water, therefore if the suction is tight the pump will exhaust the air, and then by tending to cause a vacuum, cause the water to rise and enter the pump. With a pump, the valves of which are in order, a vacuum of 27 inches (0·8 atm.) of mercury should readily be obtained. The water once entering the pump barrel must leave by the delivery outlets. Some persons consider the loss of power in changing from the circular action of a motor engine to the reciprocating pump so prejudicial as to cancel the advantages of the small clearances and the consequent obtainable higher vacuum.

Rotary pumps have a limited use in America and upon the Continent. They consist of a pair of working vanes or cams in a casing designed so as

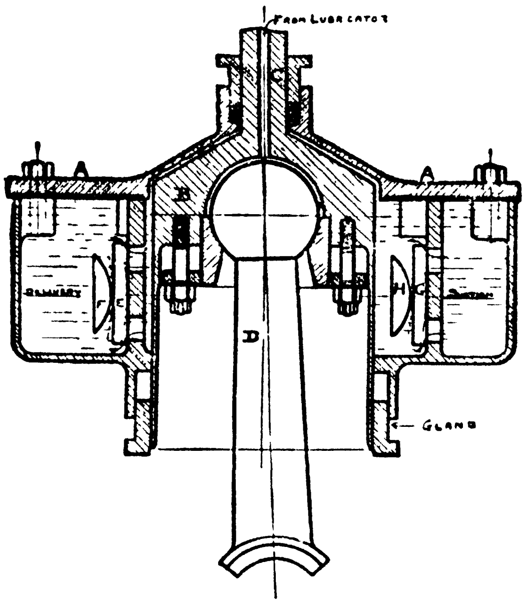


Fig 197*a* – Section through Valve Chamber.

to be interlocking and working together. As the vanes revolve, the water is drawn into the pump and carried round by the curved vanes upon the arms, and forced out at the discharge outlet of the pump. The number of vanes vary, but seven is considered a satisfactory number upon each arm.

A portion of the water drawn into the pump is carried back into the suction pipe between the arms; the percentage of this unavoidable slip is increased, of course, by the wear between the casing and arms. When gritty or dirty water is being pumped, the faces and edges of the vanes soon wear, with the result that the slip is so aggravated that for fire extinction purposes this type has for some time been practically abandoned.

As mentioned above, the slip in a rotary pump is considerable, and the

displacement of the rotating arms will not indicate the number of gallons per minute the pump will deliver. The speed at which the pump can be run depends largely upon the size and arrangement of the water passages, also upon the manner in which its power drive, gearing and shafting have been fitted up. It is stated that experience with the pumps now in use shows that owing to the losses due to slip and friction in the pump

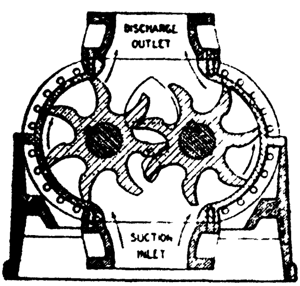


Fig. 198.—Bucket Cam.

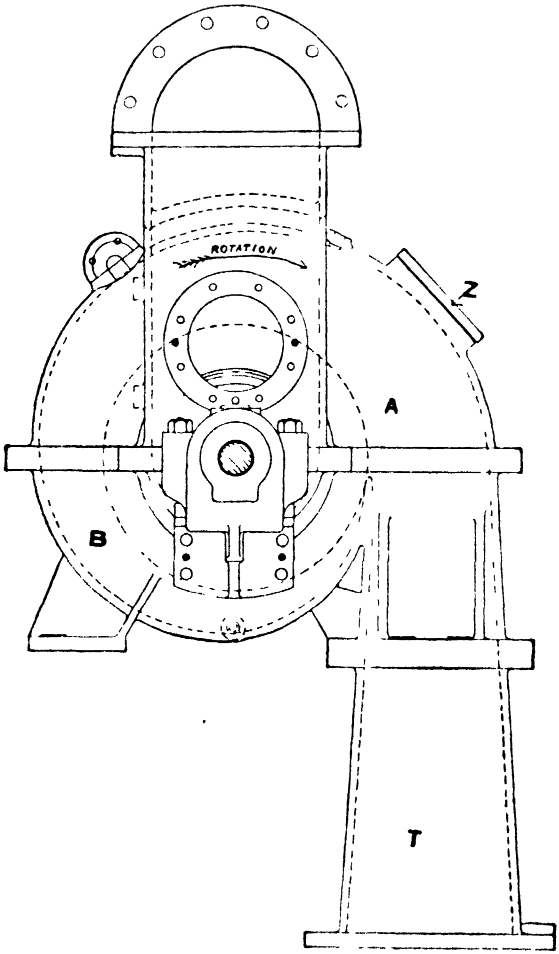


Fig. 199.—Single Stage Centrifugal Pump (Cross-section).

and driving gear, 12 H.P. is required for each 100 gallons (454 l.) per minute delivered at 100 lbs. (6·8 atms.) pressure. 30 H.P. is the usual allowance for each good 1¼ inch (0·03 m.) stream.

Fig. 198 shows a seven fan standard rotary pump which, when new and in good order should give the following results:—

Nominal Gallons per minute.	Approximate width of Vanes	Approximate distance between centres.	Approximate Revolutions per minute.	No. of 1¼ in. (0 028 m) streams.	Approximate H.P. required for 100 lbs. (6·8 atms.) pressure.
	Inches.	Inches.			
500	8	7 or 8	275	2	60
750	9 or 10	8 or 9	275	3	90
1,000	10	9 or 10	250	4	120
1.500	12	10 or 12	250	6	180

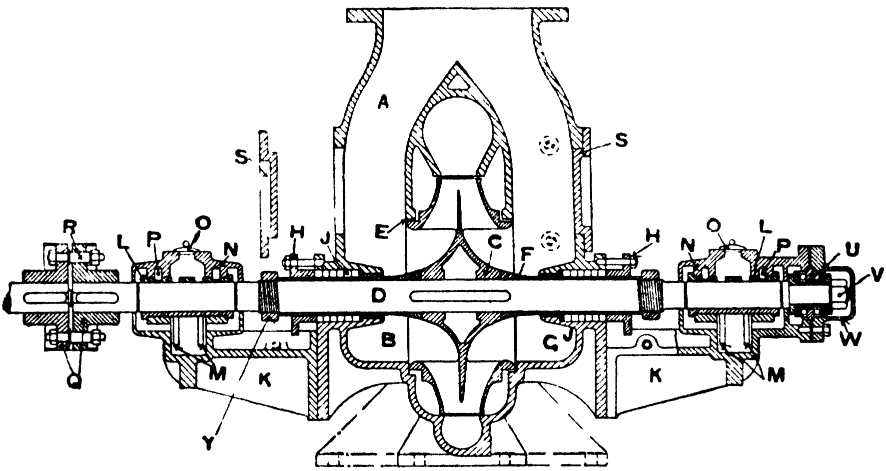


Fig. 199*a*.—Single Stage Centrifugal Pump (Sectional Elevation).

Ref. Letter.	Description.	Material.
A	Casing: Top half.	Cast Iron.
B	Casing: Bottom Half.	Cast Iron.
C	Disc.	Gunmetal.
D	Spindle.	Non-Corrosive Nickel Steel.
E	Eye Rings.	Gunmetal.
F	Sleeve.	Gunmetal.
G	Neck Bushes.	Gunmetal.
H	Gland Collars.	Cast Iron.
J	Water Seal Lantern Rings.	Gunmetal.
K	Bearing Brackets.	Cast Iron.
L	Bearing Bushes.	Gunmetal
M	Oil Rings.	Gunmetal.
N	Bearing Caps.	Cast Iron.
O	Bearing Oil Hole Covers.	Brass.
P	Dowel Pins.	Steel.
Q	Couplings in Halves.	Cast Iron.
R	Coupling Pins.	Steel with Leather Washers.
S	Inspection Doors.	Cast Iron.
T	Delivery Extension Pipe.	Cast Iron.
U	Double Locating Collar (Hoffmann)	Steel.
V	Spindle Nut.	Steel.
W	Cap for Locating Collar.	Cast Iron.
Y	Nut: Sleeve for Spindle.	Steel.
Z	Inspection Cover.	Cast Iron.

Centrifugal Pumps (see Figs. 199 and 199*a*) are those in which there are no plungers or pistons, and the pump does not work by displacement. It is simple in the extreme. The essential parts are the casings, usually of cast iron, and the impeller, sometimes of cast iron and sometimes of bronze. Attached to the impeller are curved vanes, six to 12 in number, according to the design of the maker. The water entering round the shaft at the centre or "eye" of the impeller is at once acted upon by the centrifugal force set up by the impeller and flung outwards, so to speak, causing pressure energy at the vane tips and a vacuum at the centre. The modern types have been designed for a motor drive. Higher pressures may be secured by increasing the speed, but in order to avoid excessively high speeds two or more impellers are arranged in series, forming the multi-stage pump (see Fig. 200).

The centrifugal pump is well adapted for being driven by a motor, as the speed of the pump and the prime mover may readily be made the same, thus permitting direct connection.

To obtain a fire pressure of 100 lbs. (6·8 atms.), two stages at least appear to be necessary.

In order to avoid very large impellers and to secure a reasonable efficiency, there are advantages in using the four-stage pump. The four-stage pump permits of lower speeds, a better balancing of the end thrusts, and being of smaller diameter the casing is the better able to withstand the internal pressure without the casting being unduly heavy.

In pumps consisting of more than four-stages the casing should be of gunmetal.

The speed of a pump should not exceed 1,800 revolutions per minute.

The efficiency and power required to drive four different sizes of pumps at their full rated capacity, based on the required efficiencies, is about as follows :—

Size of pump. Gallons per minute.	No. of 1¼-inch (0·03 m.) streams.	Efficiencies per cent.	Horse Power required.
500 (2,270 l.)	2	50 to 55	64 to 60
750 (3,405 l.)	3	55 to 60	88 to 80
1,000 (4,541 l.)	4	60 to 65	107 to 100
1,500 (6,811 l.)	6	65 to 70	148 to 138

The efficiency of centrifugal pumps falls away rapidly on the small sizes. The above efficiencies should be obtained, not because the cost of the power used during a fire is of importance, but because a much lower efficiency would mean a larger motor with consequently enhanced first cost, and heavier weight.

Centrifugal pumps are not only being used for lifting water by the suction from ponds and rivers, but are extensively employed in towns to act as "booster" pumps by receiving their water from the hydrants upon the street mains at 15 to 30 lbs. (1 to 2 atms.), and delivering it into the fire hose at 140 lbs. (9·5 atms.).

Where a pump is required in such a position that involves a lift, a foot valve should be provided, and if it is a fixed pump, provision made for clearing the valves by means of handholes.

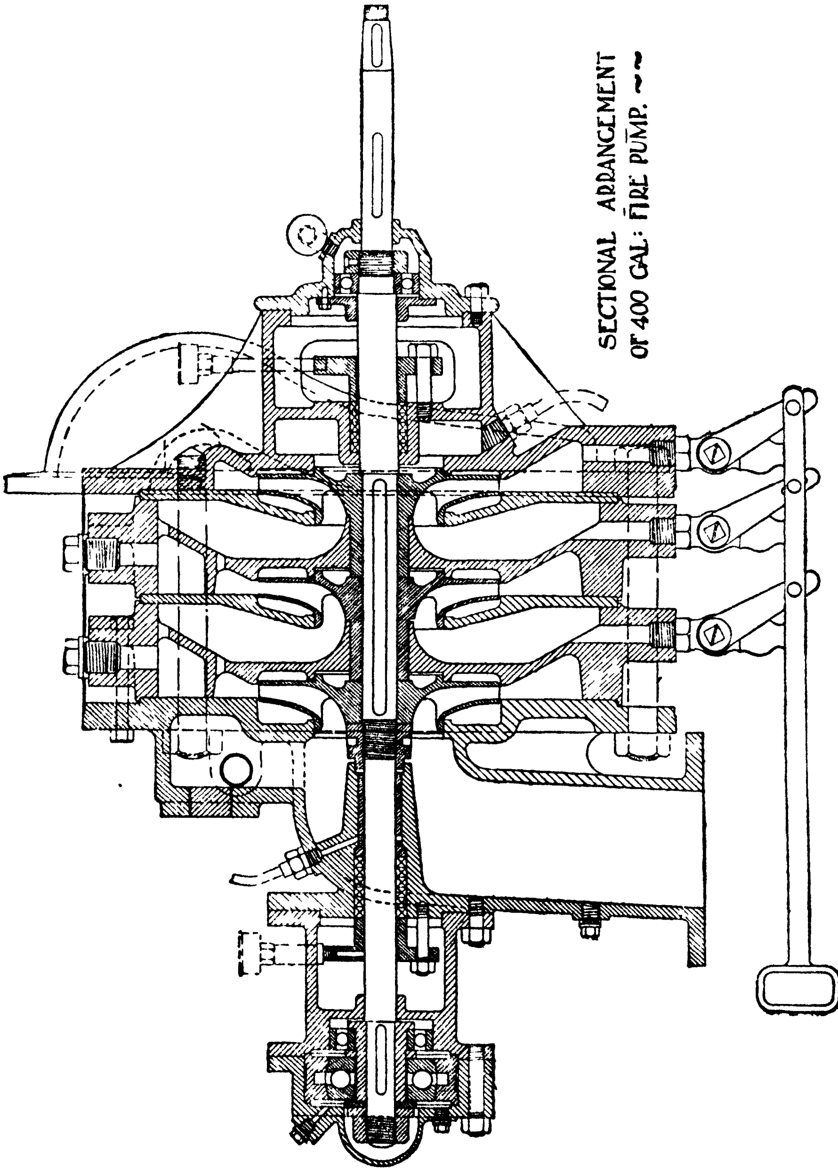


Fig. 200.—Multi-Stage Centrifugal Pump.

Foot valves should be of a design and construction that they do not unduly restrict the flow of the water towards the pump. Unless the water

supply is exceptionally clean, a strainer should be provided. If space can be allowed, a set of double screens are advisable, so arranged that one set can be removed for cleaning at a time. The screens should be of brass or copper wire (12 B.G.), with ½-inch (0·013 m.) mesh, and of 1 square inch (645 mm.^{2}) for every rated gallon per minute in the size of the pump.

Where the water supply is clean the wear upon the fans or blades of the impeller is small, but in supplies containing sand, shells, or vegetable matter, the water in passing at high speed causes a grinding action upon the sharp edges of the vanes, which sooner or later will materially increase the slip and thus reduce the efficiency of the pump.

The indispensable requirements demanded from all fire appliances is that they are ready for use and that they can be transported to the fire. Remember that the motor will get out of order, and when it does the whole appliance is disabled. Spare parts should be kept at hand and arrangements made with a repair shop to undertake and carry out the work at short notice. In most cases a duplicate machine is required unless an appliance can be obtained upon loan from another station.

Section.

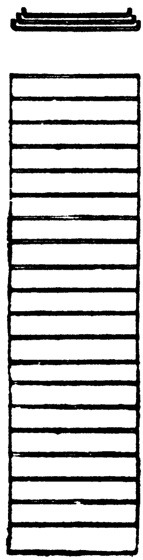


Fig. 201—Plan.

It must be remembered that horses or men drawing a vehicle lift the fore-carriage with each pull, tending to raise the front wheels on to fresh ground, while a motor with the propelling force applied through the hind wheels tends to force the front wheels into the ground. In order to, in some way, overcome the difficulty in passing over soft ground, steel plates (Fig. 201) can be obtained, 5 feet (1·52 m.) long, with half-round cross strips every 3 inches (0·076 m.); in order to stow they are of varying widths from 13½ (0·32 m.) to 16 inches (0·4 m.), 2½ inches (0·064 m.) deep on the flange, made in sets of 4 or 6. Each plate weighs about 56 lbs. (25·4 k.). When in use the plates are laid end to end on the soft ground, and as soon as the motor has passed over a plate, it is taken up and placed in front of the pump again.

Many brigades have been successful in fitting horse-drawn steam fire engines with draw-bars by means of which any motor vehicle can be attached and used as a tractor. Great care is always required in towing, and particularly so in the case of a heavy, high-mounted machine, like a fire engine. Turning corners and descending hills require extreme care, or the heavier machine may skid and come broad-side on or turn over.

If the motor vehicle for towing is the property of the brigade it can with advantage be fitted up as a tender for the conveyance of the men, hose and small appliances. To transfer the weight from the machine to be towed to the tractor has the double advantage of rendering the machine more under control, and the extra weight gives the wheels of the tractor a better grip upon the road.

The Petrol-Electric Motor consists of a chassis fitted with a petrol engine of the usual type, which drives an electric dynamo, the electric current from which flows through a controller to an electric motor, which in turn drives the chassis by means of the usual type of live axle. No clutch or gear box is used, and the engine speed is not tied in proportion to the chassis speed,

but is simply in proportion to the demand which the road resistance and gradient makes on the engine.

This type of motor has for some time been used for Escape Vans and Long Ladders ; in the latter case the electrical power is also used with great simplicity and advantage for raising and extending the ladders, and presents great possibilities with remarkable flexibility. In well worked out designs, evolved from experience, it should outbalance the disadvantages of the additional apparatus and the inevitable transmission losses.

From a petrol-electric chassis an electric centrifugal pump can be worked upon the chassis or the pump unshipped and manhandled into any position so long as it is within reach of a flexible cable carried upon a drum on the motor.

The electric current can also be used to supply light, air pumps, or smoke helmets, or any temporary electric supply.

The following is a practical example of how the same law of hydrostatics, as mentioned on p. 37, comes into force when motor pumps are set to work in series.

In 1908 considerable attention was given to the fire protection of St. Paul's, see Chap. III., p. 91, and upon completion of the work careful tests were made in the summer of 1911. First, a jet from the hose attached to the hydraulic pump in the crypt was tried. It gave a splendid stream of solid water rising over 100 feet (30·48 m.), even the least spray was not seen until about one-third of the distance. Secondly, a length of 2¾-inch (0·07 m.) rubber-lined hose was suspended from the balustrade of the Golden Gallery, 288 feet (88 m.) above the street level, to the ground. This was attached to one of the pumps. A length of hose was then connected from this pump to a second pump, which in turn was joined up to a street hydrant. The pressure in the main at the hydrant was 30 lbs. on the square inch (2 atms.). When all was ready, the hydrant was turned on, and the first motor pump received the water at this, 30 lbs. (2 atms.) pressure, this pump added 105 lbs. (7 atms.), and boosted up the original to 135 lbs. (9 atms.), at which pressure it entered the second pump attached to the line of the hose suspended from the Gallery. The second pump in turn added another 105 lbs. (7 atms.), making a total pressure on the delivery outlet of the second pump of 240 lbs. (16 atms.). It was not thought desirable to boost the water above that pressure, as 240 lbs. (16 atms.) was considered about the maximum pressure the pump cylinder, 23 inches (0·58 m.) in diameter, would stand. Additional pressures would require an especially strong hose and pump. From the Golden Gallery a 1-inch (0·025 m.) jet was used which projected the water above the top of the Cross, 78 feet (24 m.) higher than the Gallery, and a total height of 366 feet (111·5 m.) above the street.

Now, to calculate the pressure required at the pump, and taking the vertical height of the 1-inch jet to have been 92 feet (28 m.) and the height of the vertical hose 300 feet (91 m.), with a further 100 feet (30 m.) of hose upon the ground from the building to the pump, making a total length of 400 feet (122 m.), by referring to Table on p. 112, it will be found that 90 lbs. indicated pressure at base of a branch pipe will give a 92-feet (28 m.) jet of water, and to force that through 400 feet (122 m.) of 2½-inch (0·064 m.) unlined canvas hose requires a pressure of 257 lbs. (7·57 atms.) at the pump.

In the trial mentioned above the hose used was $2\frac{3}{4}$-inch (0·07 m.) rubber lined, and as explained on p. 106, it would therefore only require 62 per cent. of the 257 lbs. pressure that is necessary for $2\frac{1}{2}$-inch (0·064 m.) hose—viz., 159 lbs.

To calculate these pressures refer to the tables.

The friction in good rubber-lined hose $2\frac{1}{2}$ inches (0·064 m.) nominal diameter and passing 200 gallons (908 l.) per minute is 13 lbs. (0·9 atm.) per 100 (30·5 m.) (p. 106). The length of hose used was 400 feet, therefore 13 × 4 =	52 lbs. (3·5 atms.) per 100 feet (30·48 m.).
Now as the hose used was $2\frac{3}{4}$ inches (0·07 m.) the friction would only be 62 per cent. of the 52 lbs. (p. 106) =	32 lbs. (2·2 atms.) per 100 feet.
The pressure of a column of water 300 feet (91·4 m.) high is (p. 98) . .	130 lbs. (8·8 atms.).
The pressure required at the base of the branch pipe to project a 1-inch (0·025 m.) jet 92 feet (28 m.) is (p. 112), ...	90 lbs. (6·1 atms.).
The total pressure required at pump, .	252 lbs. (17·1 atms.). This is

5 lbs. (0·34 atm.) less than given in the table on p. 112, and 12 lbs. (0·8 atm.) more than the actual pressure used in the second pump at the trial.

Small two-wheel motor trailer pumps are made for use of districts with small fire risks. The sizes are from 100 to 250 gallons per minute. They can be drawn by hand or trailed along behind any horsed or motor vehicle.

CHAPTER XI.

HOSE.

HOSE (hosa) is a common word in many Teutonic languages. The origin is Anglo-Saxon.

The name is used for forms of long stockings as a covering for the thighs. In the early part of the 17th Century the name "hose" was given by the Dutch to the newly invented flexible pipe used with engines for conveying water to extinguish fires, etc. With firemen the word "*Hose*" is used to denote *delivery hose* and "*Suctions*" to denote *suction hose.*

The use of leather pipes for the conveyance of water is of very ancient origin. Pliny relates that the ancient inhabitants of the Island of Andros obtained fresh water from the springs at the bottom of the sea by sinking a bell of lead over the spring, to the top of which bell a leather pipe or tube was attached, and by means of which the fresh water was conveyed to the surface.

In Chapter I., p. 33, will be found an account of how at the present day the inhabitants of part of the Island of Teneriffe obtain good fresh water from below the sea high water mark.

After a disastrous fire in Rome every citizen was required to keep in his house "a machine for extinguishing fire." Many, therefore, provided a "Sipho" or syringe, which was sometimes out of order or not available.

Apollodorus, the Architect of the Emperor Trajan, recommended in such a case that when a fire occurred in the upper part of a house the inhabitants should fill leather bags with water, connect *long pipes* to them and then by compressing the bags the water would be driven out of the end of the pipes with considerable force and to some height on to the fire. It is natural to assume these pipes were what are now known as hose.

The introduction of flexible tubing or hose through which the water could be forced up by the pumps in the direction of and on to the fire was an immense assistance to the Firemen, allowing as it did the pump to be placed at the source of the water supply, while the other end was free, so that the direction of the water and the stream which issued from the branch pipe could be changed at will. The method of manufacture and the strength of materials used depend naturally upon the particular use to which the hose is to be put.

As mentioned in Chapter X., the early fire engines consisted of a pump and tank which had to be filled by means of pails, the lower part of the pump being fixed to the bottom of the tank and the water forced through metal play pipes fitted with a reducing collar to form a jet. In order to use the engine to the best advantage the pump had to be placed as near to the fire as the men could safely work, with the result that the effective range of the water was very limited and many places could not be reached at all.

About 1672 a Dutchman named Jan van der Heijden, hit upon the idea of inserting a leather hose between the pump and the jet nozzle. The leather

first used was made of strips of hide sewn together at the seams, but, as may be imagined, it was found to be very defective at first; in time, however, the process of manufacture was improved. It does not seem to have been used in this country before 1760. Sewn leather hose is still to be found in some of the old Fire Stations that have been in charge of men, who, having few fires, are able to look after the appliances, and give special attention to the leather.

The original mode of making leather hose by sewing the seams or edges together remained unchanged from 1672 to 1807 or 1808, when Messrs. Sellers & Pennock, of Philadelphia, substituted rivets for this purpose.

In 1819 Mr. Jacob Perkins, of London, seems to have been the first in England to improve the method of making leather hose watertight and employing copper rivets.

Leather hose, if well made, from the best English butts, tanned with oak bark, cut in lengths not exceeding 4 feet 9 inches long, and only from the hind or prime part of the butt, excluding all neck and belly, is a very strong and durable article that will withstand very rough usage. With moderate care and attention it will last fifty years, and it is also easily repaired, but the first cost is high.

As the leather is thick and the seams very frequent, the flow of water is much retarded, with the result that in long lengths most of the pressure at the pump is lost, see p. 104 on loss due to friction.

On account of the bulk and weight, leather hose is only made in 40 feet (12·8 m.) lengths, requiring gunmetal couplings at either end.

The average weight of a 40 feet (12·8 m.) length of 2-inch (·051 m.) leather hose with couplings, leather beckets, strap, etc., will be from 48½ (22 kg.) to 52 lbs. (24 kg.), whilst 100 feet (30·48 m.) of 2⅜-inch (·06 m.) rubber-lined canvas hose complete will be from 50 (22·7 kg.) to 60 lbs. (27·2 kg.) and 100 feet (30·48 m.) of 2⅜-inch (·06 m.) unlined canvas hose complete 30 (13·6 kg.) to 35 lbs. (15·9 kg.).

The average dimensions of a coil of leather hose made up ready for use are 20 inches (0·53 m.) in diameter by 4½ inches (0·11 m.) in width.

A specification and instructions in the care and management of leather hose will be found in the Appendix.

The advantage of leather hose is that it is strong and offers a good resistance to external injury. It possesses, however, the great disadvantages of insufficient flexibility, in consequence of which it is difficult to handle, it occupies too much space on the fire appliance carriages, and will only (except in the small diameters), withstand 120 lbs. (6 atms.) pressure per square inch. In order to keep leather hose flexible to some extent, it must be regularly greased, and this is especially necessary along the seam, so as to ensure it being as much as possible watertight.

The quantity of water contained in a 40-foot (12·8 m.) length of new leather hose under pressure varies slightly according to the elasticity of the leather, but it is found on an average to be almost 10 gallons (45·4 l.) or 100 lbs. (45·5 kg.). The total weight, therefore, of each length of hose when in operation may be roughly estimated at about 1½ cwt. (76·2 kg.), and, therefore, when working on buildings 70 feet (21 m.) to 80 feet (24 m.) in height, the total fixed weight suspended by a line would be about 3 cwt. (152 kg.).

Hose for domestic or garden use is often made of indiarubber or a composition of rubber and other ingredients. Up to 1874 most of the hose for

fire brigade purposes was made of leather, then Flax Hose began to overcome the prejudice of the old-fashioned firemen and gradually came into use.

At first Flax hose was entirely woven by hand and much of the best hose is still so made. About 40 years ago, mechanical circular weaving was made applicable to woven hose. During the last few years weaving machines have been so improved that machine-made hose can now be obtained which is nearly equal to hand-made.

The requirements with which hose must comply are (1) Sufficient strength, (2) resistance to leakage, (3) handiness, (4) the greatest possible compactness for stowing upon the appliances.

Flax threads wet are stronger than when dry, this must be borne in mind when making tests and sufficient time allowed for the fabric to become saturated.

Porosity tests made by the author in 1915 with a 10-ft. (3·05 m.) length of 7 years old, but unused flax hose, were as follows. The hose nominally called

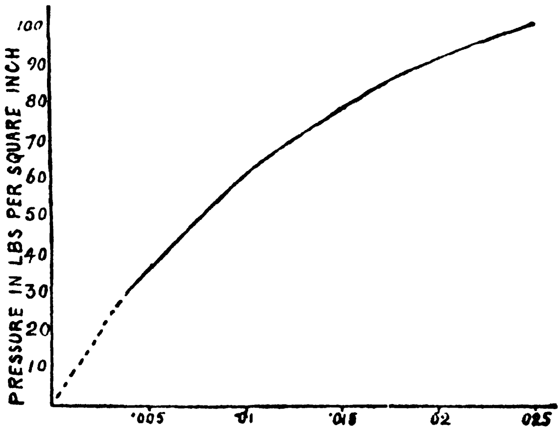


Fig. 202.—Leakage in Gallons per square foot per minute for a Hose, internal diameter 2·86 inches.

2¾-inch (0·069 m.) was found to be 2·86 inches (0·073 m.) in internal diameter, and contained 782 cubic inches (0·0128 m.^{3}) = 2·8 gallons (12·7 l.), or 28 lbs. (12·7 kg.) of water.

The average pressure upon the inside of the hose due to weight of a column of water 10 feet (3·05 m.) high is 2·17 lbs. on the square inch (0·14 atm.). The temperature of the air was 42° F. (5·5° C.) and of the water 49° F. (9·4° C.).

The length of hose was suspended vertically with a pressure gauge on the bottom end, which was fitted with couplings and capped. The hose was filled with water. The water was kept at a constant level in the hose and the leakage recorded at one minute intervals, for the first 20 minutes, and then each 10 minutes to a total of 90 minutes.

The water exuded from the hose was measured into a receptacle placed upon scales. The water evacuated during the first 2 minutes weighed 1·9 lbs. (0·86 kg.). After the fabric was wet the leakage became gradually less, as shown by Test No. 1 and Fig. 202.

Other tests with water under pressure were made, and the results are given in Tests Nos. 2, 3, and 4.

Test No. 1.

Time taken to fill the 10 feet (3·05 m.) of Hose—54 seconds.

Minutes from filling.	Water exuded per minute from the 10 feet of hose average.				Total water exuded to time.			
	Ozs.	Kg.	Galls.	l.	Ozs.	Kg.	Galls.	l.
1	31·0	·879	·1938	·881	31·0	·88	·19	·88
2 to 9	1·5	·042	·0094	·042	54·5	1·55	·34	1·55
9 to 20	1·0	·028	·0063	·027	66·0	1·87	·41	1·87
20 to 30	·85	·024	·0053	·024	74·5	2·16	·46	2·1
30 to 40	·725	·023	·0045	·020	81·75	2·32	·51	2·3
40 to 50	·6	·016	·0038	·017	87·75	2·49	·54	2·5
50 to 60	·525	·015	·0033	·015	93·0	2·63	·58	2·6
60 to 70	·475	·013	·003	·014	97·75	2·77	·61	2·7
70 to 80	·45	·012	·0028	·013	102·25	2·9	·63	2·9
80 to 90	·4	·011	·0025	·011	106·25	3·0	·67	3·0

Test No. 2.

At a pressure of 30 lbs. per square inch (2 atms.), ·021 kg. on mm.² applied to top of column of water by force pump. Other conditions as in Test No. 1.

0 to 5	6·5	·184	·040	·172	32·5	·921	·203	·927
5 to 10	5·94	·170	·037	·168	59·5	1·69	·372	1·690

Test No. 3.

At a pressure of 60 lbs. per square inch (4 atms. or ·042 kg. on mm.²) applied to top of column of water by force pump. Other conditions as in Test No. 1.

1 to 4	18	·510	·113	·513	68·5	1·942	·491	2·23
Fifth minute	15·5	·439	·097	·441	84·0	2·381	·525	2·36
Average of 5 minutes	17·4	·482	·109	·495				

Test No. 4.

At a pressure of 100 lbs. per square inch (6·8 atms. or 0·07031 kg. on mm.²) applied to top of column of water by force pump. Other conditions as in Test No. 1.

8 minutes	40·6	·25	·25	1·135	324·8	2	2·03	9·23

From the above it will be seen that with simply the weight of the column of water at ordinary atmospheric pressure the leakage dropped from ·02 gallon (0·09 l.) per foot run of hose per minute to ·0005 gallon (·0014 l.) per foot per minute at the end of one hour, due to the expansion of the fibres. With a pressure of 30 lbs. (2 atms. or ·021 kg. on mm.²) the leakage at

the end of 10 minutes was about ·004 gallon (·018 l.) per foot per minute. With a pressure of 60 lbs. (4 atms. or ·042 kg. on mm.^{2}) the leakage at the end of 5 minutes was about ·01 gallon (·049 l.) per foot per minute. With a pressure of 100 lbs. (6·8 atms. or ·0703 kg. on mm.^{2}) the leakage at the end of 8 minutes was about ·025 gallon (·114 l.) per foot per minute.

The strength and thickness of woven hose depends on the material used in the weaving. Its strength must be such that it can stand without bursting the pressure of the water—*i.e.*, that of the engine—even after many years use, while sufficient tightness is necessary to prevent needless loss of pressure and unnecessary damage by water.

By the weaving alone, hose can be made sufficiently watertight, to withstand a fairly high pressure; but it would become rigid and difficult to manipulate. Newly woven hose will always allow the passage of a considerable quantity of water by sweating, as it is called. If a suitable material has been selected for weaving the fabric, and, after the sweated water has been removed, for instance by the passing hand over the hose, the sweating will practically stop, and the hose, if it has no "pinholes" will nearly be watertight. The water causes the fabric threads to swell, thus closing up the interstices or pores in the fabric. This swelling is, in part, permanent, so that a hose which has been several times used and dried, when again put into use is at once more watertight than it was before.

Materials which swell in the above mentioned manner and are used in the manufacture of hose are Flax, Hemp, Ramie, China grass and Cotton.

Hemp.—Before the war large quantities of cheap hemp hose were produced by German manufacturers, principally, however, for other purposes than fire brigade work, although the better class of hemp hose were used fairly largely by many continental fire brigades. The fibre is strong but brittle and lacking in elasticity; it is coarser than flax, and does not absorb the water to anything like the same extent. A hemp hose has to be driven very closely together in the weaving to make it sufficiently watertight, and this fact, as also the nature of the fibre, makes it a very hard stiff inflexible hose, difficult to handle, very liable to crack and break on the edges, and, therefore, lacking in durability.

Ramie and *China* grass, having such excellent qualities as fibres should have full consideration. The chief difficulty in the way of their use has been the lack of an efficient process, (other than hand labour) for properly decorticating and degumming the fibre from the rest of the plant. Experimental lengths have been made of Ramie, but they were so unsatisfactory that its employment was not proceeded with. Although the fibre in itself is perhaps quite as strong as flax, there are also other obstacles to its use. It is a shorter fibre than flax, and in the form of yarn is, therefore, more brittle. In a series of 20 breaking tests of a certain size of ramie yarn and of the same size of flax yarn (both being of the best quality of their respective kinds), flax yarn stood an average breaking strain, to the extent of 12½ per cent. more than the ramie.

When wet both yarns were tested and the flax stood an average breaking strain of 16¾ per cent. more than the ramie. The reason for the difference between the breaking strengths of the two yarns being greater when wet, is that, owing to the nature of the fibre, ramie is less absorbent than flax, and therefore does not gain strength to the same extent by saturation. Other

pressure tests showed that the bearing strength of ramie hose compared with similar tests of flax hose of the same weight, and woven upon the same loom, was 25 per cent. less than the flax hose.

Cotton is of no use for the manufacture of unlined canvas hose for use under water pressure, it stretches so much in length under even a very moderate pressure as to open the pores of the fabric to such an extent that the water escapes through the canvas nearly as fast as it can be pumped in.

Cotton hose can, of course, be made watertight, by lining with rubber, but this will be dealt with more fully later on.

Jute should never be used for hose, it is altogether too coarse and weak a fibre for the purpose.

Flax is, without any doubt whatever, much the best fibre for the manu facture of fire hose. If the right grade of flax is used, it has the necessary strength to withstand the required pressure; it has the needful wearing properties; it absorbs the water and closes up under pressure as no other fibre will, and moreover, if properly cleaned and finished, it makes a soft and pliable fabric which is easy to handle and is much less liable to crack and break and to become damaged by chafing, than is the case with hose woven from harsher and less "kindly" fibres.

The quality of the hose depends not only on the material but on the composition of the fabric, and it is upon this question of the composition that the experience of the manufacturer tells.

A good firm of manufacturers (not the merchants or factors) can arrange the material to suit almost any conditions, and hose should only be purchased from firms with a good reputation.

It is, however, expedient that Firemen should understand the general fundamental principles upon which hose is made. The fabric consists of warp and weft. The warp thread is that which runs in the longitudinal direction of the hose and the weft thread the one which is woven crosswise between the same. The warp and weft threads consist of a number of thinner threads or strands twisted together, which, in turn, consist of a number of spun fibres of raw material. The strands last mentioned are found under specific numbers in the trade; they must be so strong that they are unbreakable, or, at any rate, difficult to break by hand. The larger the number of strands in warp and weft the stronger the warp and weft thread will be. With the increase of that number, however, the thickness of the warp and weft increases, and, therefore, the fabric becomes coarser and less watertight. It is here that the quality of the raw material comes into prominence. The stronger the material the thinner the threads may be, and, therefore, with one and the same strength the number of those threads which can be put into the same thickness of warp or weft will be greater. The finer the fabric the tighter the hose. To secure a fine and regular fabric the warp thread is made thinner than the weft thread. The crossing of the warp and weft thread is called a "shot" or "pick" the *greater the number of shot or picks on the periphery of the hose the finer, and, therefore, the more watertight is the fabric.*

In first class hose the weft may not consist of less than 20 strands, if rubber-lined, or 12 if unlined; should the number be reduced below 12 the result is an inferior quality of hose. It should, in this connection, be borne in mind that it is chiefly the strength of the weft threads which run trans-

versely that determines the internal strength of the hose. The warp thread takes the external wear, and is of much less importance in determining the hydraulic strength of the hose; in order to obtain a fine fabric, it is, as a rule, made of two 3-strand or two 4-strand threads laid close together. The weft thread is moreover considerably thicker than the warp thread.

The weaving of the hose, though called circular weaving, is not effected by weaving the weft threads through warp threads held cylindrically, but by passing them through two double *flat* rows of warp thread held one below the other, which rows, therefore, after the weaving, are of the width of the hose measured flat; in this way the two folds or selvedges which the hose possesses when delivered, originate. These folds or selvedges are the weak points of the hose, for the reason that the process of weaving is most difficult at the fold or selvedge. When selecting a hose, therefore, care must be taken that the weaving at those folds is well carried out, which will be apparent from the fact of the shots or picks at the folds lying absolutely straight in a line.

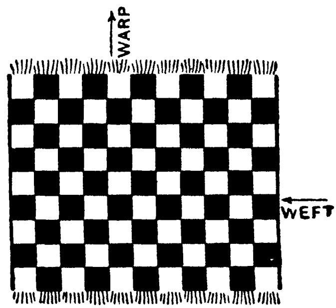


Fig. 203.

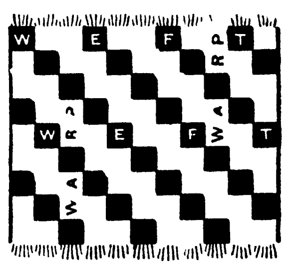


Fig. 204.

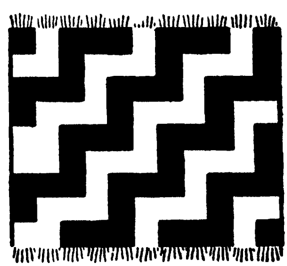


Fig. 204*a*.

As will be understood from the above a purchaser cannot determine the properties of a hose from inspection only. In most cases it is preferable to state what is required; the manufacturer can then submit the hose most suitable for the purpose.

Manufacturers, by rolling the hose, reverse the position of the fold or selvedge from the edges to the centre of the flat part of the hose, this considerably assists in the careful examination of the hose for faults before it leaves the mill.

For the manufacture of hose two kinds of fabric are in use, the plain fabric and the diagonal or twilled fabric. In the case of the plain fabric the weft passes alternately over one warp and below the next one, while the shots or picks are in regular connection in the manner as shown on Fig. 203. In reality very little is seen of the weft thread, the latter being mostly covered by the two nearest warp threads, which, when the weft is shot in, flatten out.

In the case of the diagonal (twilled) fabric there is an uneven distribution of warp and weft thread; the warp thread does not always pass one weft

thread, but alternately 2 or more weft threads and according to the number of threads in this latter case various kinds of twills are distinguished, the shots or picks of which, therefore, form different figures.

In making the fabric for the twilled rubber-lined hose for the London Fire Brigade the shots are worked, for the first time 2 weft threads, the next time 1 weft thread is shot over, and the result is a position of the shots as shown on Fig. 204. If the warp were allowed to pass over more weft threads the fabric would be too loose and leaky for its purpose.

Fig. 204A shows three weft threads, the next time 1 weft thread another 3 again, but this is not a usual weave so far as canvas hose is concerned.

On Fig. 204, viewing the hose from the outside, the white squares represent the run of the warp and the black ones the run of the weft; consequently, twice as much warp as weft is seen. In reality the weft threads are here again mainly covered by the warp threads. On the inner side the hose will show the reverse—*i.e.*, there will be twice as much weft as warp visible and the weft will show most.

Diagonal or twilled hose is rather stronger, but not so watertight as plain woven fabrics. In the case of unlined hose therefore plain fabrics are used, but when it is to be lined with rubber, twilled fabrics being more pliable can be used.

Remember water communicates its pressure equally in all directions. See pp. 34 to 37.

It need hardly be said that hose with small diameter and the same fabric is stronger than hose of large diameter. In proportion as the diameter of the hose gets larger, the effect on the fabric of the pressure of the water contained therein will increase. Therefore, in order to make large size hose equal in strength to the small sizes, heavier threads have to be used, and the heavier the threads the more porous is the fabric.

In America where rubber-lined hose made of cotton is used it is customary, in order to increase its strength and durability, to weave the same with a second or even a third cotton cover or "Jacket." This, however, makes the hose very weighty and bulky.

As the periphery of a circle is proportional to the diameter (d), so is the section area proportional to the square of the diameter (d^2).

The theoretical pressure bearing strengths of different sizes of canvas hose, with walls of the same thickness and quality are in inverse proportion to their diameters, therefore a 2-inch (·05 m.) hose will withstand 25 per cent. more than the same hose 2½ inches (·064 m.) in diameter.

Taking a 2½-inch (0·64 m.) hose as being capable of withstanding, say, 300 lbs. pressure on the square inch (20·4 atms.) then a 2-inch hose would withstand 375 lbs. (25·5 atms.) or one-fourth stronger.

Although when first class material is used a great degree of tightness against leakage is secured with a woven flax or hemp hose, the impermeability is nevertheless not complete. The leakage of such hose, however, is chiefly due to small defects in the fabric, the shifting of threads (which may sometimes be put right by rubbing with the thumb), or external injury whereby leaks are caused, sometimes of a very considerable character. As is shown in Chapter III., rough hose has the drawback of causing great loss in the effective power of the water supply due to the friction of the water on the periphery of the hose. In order to meet this loss of efficiency the method

has been adopted of making hose with a rubber lining—*i.e.*, covering inside with a layer of vulcanised rubber.

Rubber is fundamentally the sap of a tree which is met with in the tropics (not to be confused with the inelastic guttapercha which is chiefly used for the insulation of electric wires). The best quality is the original native South American Para-rubber (*Hevéa braziliensis*), which is really the only species which should be used for first class lined hose. Para-rubber trees have been extensively planted in the Malay States, and large supplies of excellent rubber are now exported from these new plantations.

In 1839 investigations made by Charles Goodyear in the U.S.A. showed that the effect of mixing 3 per cent. to 15 per cent. of sulphur with rubber and subsequently heating [in practice under pressure and at a temperature of from 240° F. (116° C.) to 300° F. (149° C.) (being the temperature above that at which the mixture melts)], was to cause a complete change in both the physical and chemical properties of the rubber.

On vulcanisation rubber loses its adhesiveness, it can be increased in hardness up to the extent of becoming brittle and by suitable conditions of vulcanisation, any degree of elasticity can be obtained. The colour of vulcanised rubber gradually deepens as the coefficient of vulcanisation increases until the deep black of hard rubber (ebonite) is arrived at.

For hose lining, rubber that will stretch three times its length may be considered good.

The following extract from "The Manufacture of Rubber Goods," by A. Heil and Dr. W. Esch, English edition, by E. W. Lewis, sets out the mode of lining canvas Hose:—

"Canvas Hose with Rubber Lining:—The manufacture may, therefore, be briefly dealt with so that the reader may acquire some slight acquaintance with the weaving of canvas hose. Power-driven iron looms have been in use since about 1904 for making canvas hose; the old wooden hand looms, which were formerly to be found in every Thuringian peasant's dwelling, forming one branch of the cottage industry, have entirely disappeared. The manufacture is now carried out in factories only. Flax, cotton, yarn, or hemp, spun in different ways according to the size of the hose to be woven, is used. Just as in the case of all other fabrics, a distinction is made in canvas hose between the warp and the weft threads. The former, which are twice as many as are required for the width of the hose, are beamed by means of a beaming machine (Figs. 205 and 205*a*) on the warp beam. The mounting with the heddles, through which the separate threads are run, is also arranged exactly as in other looms; only the way in which the individual mountings move is different, the warp first separating into upper and under warp, the mountings then setting the upper warp so that the shuttle carries the thread through on the lathe, whereupon the under warp lifts and the weft thread is shot through in the same way. In this way the seamless hose fabric is produced. The finished tube is rolled up on a reel. About 328 yards or 300 metres can be made with one warp. The rough hose, if it is to be rubber-lined, is finished off in the following way:—

"The hose is opened out by a machine (Figs. 205*b* and 205*c*), and the tape necessary for pulling the rubber lining through is then drawn through it. The rubber lining, made on the tube machine, is partly cured for 30 minutes, then covered with solution, and drawn through the hose by means

of the tape already mentioned. The hose is then fixed on to a vulcanising cone, and firmly clamped on the tube. The lower end is connected to the condensed steam pipe, and the final vulcanisation can then be begun. It is advisable to subject the hose to a steam pressure of about 4 to 5 atmospheres (60 to 75 lbs.).

"By the high pressure the hose-lining is forced firmly on to the walls of

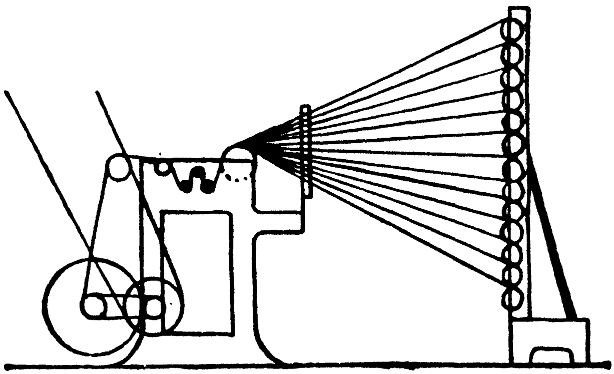


Fig. 205.

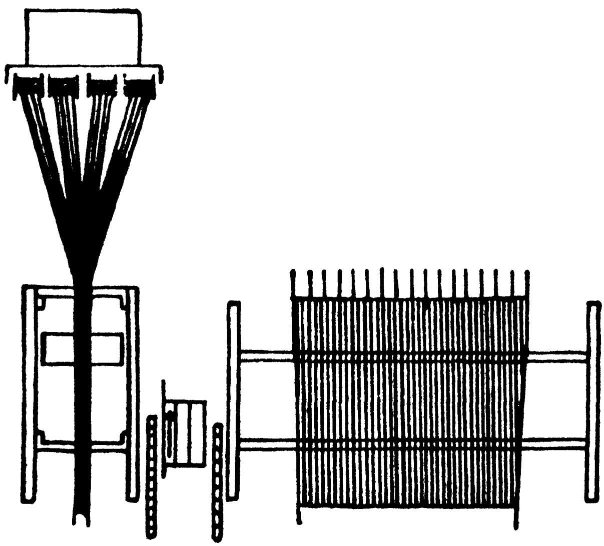


Fig. 205*a*.

the canvas hose, the solution penetrating the interstices, and the fabric and the rubber linings are thus intimately united. After lowering the steam pressure the hose is tested with a water pressure of 20 atmospheres (300 lbs.), and the hot air is then blown through it to thoroughly dry it. This method of lining hose with rubber is, however, being displaced by a new system

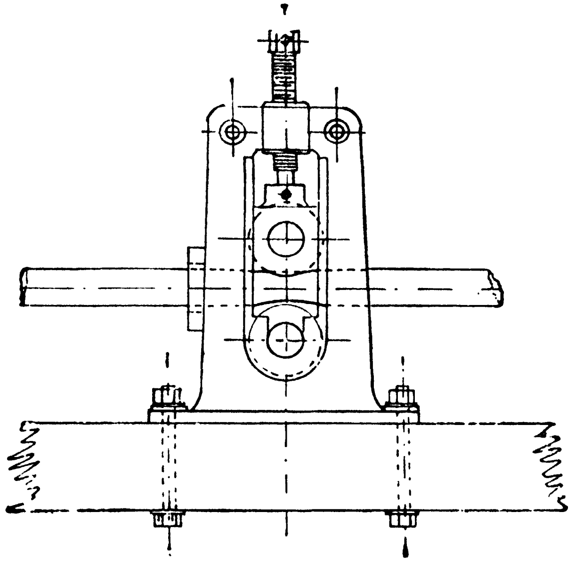


Fig. 205*b*.

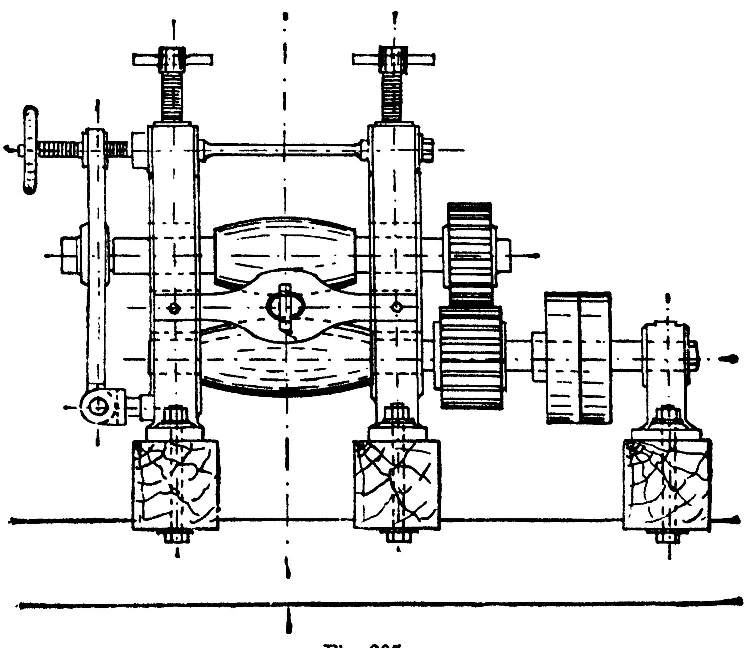


Fig. 205*c*.

which has important advantages over the old well-known method, in that there is no possibility of the hose-lining developing leaks. It is not always possible to avoid the formation of thin places in the walls of the rubber lining when drawn into the hose by the old method, and sometimes little grains or nibs of one or other of the ingredients which have been introduced into the rubber in the course of mixing, get shot out of their places, leaving holes in the rubber where leakage may afterwards occur. In the new method the canvas hose is stretched out in a heating chamber 30 meters long (98½ feet), arranged so as to be used in 3 sections. The fastening is by means of plates screwed on to the foundation plate by 6 screws. These plates are fixed to a movable frame, provided with a groove, which can be so adjusted by turning the screws that the hose inside the chamber is tightly stretched. The wires, to which are attached the rubber brushes, the object of which is to draw the solution evenly along the tube, are run through the hose, and pass over rollers at either end of the apparatus. These rollers can be mechanically driven in either direction. Between the rollers and the chamber is introduced a piece of apparatus which is connected to the hose, and into which the amount of solution necessary to put an inner coating of rubber on hose of that particular diameter is forced from the solution-holder by means of compressed air. When the separate boxes are full the driving mechanism is set in motion, and the solution is drawn through the hose by means of the brushes; the brushes are given a rotary motion and so spread the solution evenly over the inner surface of the hose. The brush, on passing through hose, carries the excess of solution into the apparatus at the opposite end, which now gets filled with solution, as previously described. Before the brush travels back through the hose in the opposite direction, hot air is blown through the hose, and this, in combination with the internal heat of the chamber, causes the solvent to evaporate. This process must be repeated until the desired thickness of rubber lining is attained. When that is the case, the chamber is closed at both ends and the vulcanisation is proceeded with. Vulcanisation is effected by means of hot air, which is led into the chamber at one end, and at the other end is driven through the hose by means of fans. It takes about five hours to proof 30 metres (about 98½ feet) of hose to a thickness of 1½ to 2 mm. (0·06 to 0·08 of an inch) and the vulcanisation occupies another 40 minutes at 145° C. (293° F.). It is not advisable to cure the hose on the cone with direct steam; by that means the solution gets forced too far into the meshes of the fabric and the hose does not turn out perfectly smooth inside. The dimensions of the 5 cm. (2 inches) long brush-rollers, as well as those of the steel discs, with rounded edges, behind them, are determined by the internal diameter of the hose.

"In spite of the consumption of solvent (benzine) this process works out cheaper, for lower quality mixings can be used and thinner coats can be put on, and still the strength of the hose will be considerably greater than that of similar hose made by the older process, while the finished article will be lighter in weight and more pliable.

"As Benzine or Carbon bi-sulphide, which will ignite by contact with hot metal, is used in these works, fires are frequent and the workpeople become so expert in the use of the wet blankets kept ready for the purpose that outbreaks of fire are smothered at once, and the outside world have

no knowledge of any mishaps. The usual cause of a fire is an electric spark caused by friction of the cloth, due in some measure to a high barometer and a dry state of the atmosphere."

The figures illustrating the lining of hose with rubber and some of the text is from "The Manufacture of Rubber Goods," by Heil & Esch, and "The Chemistry of India Rubber," by Weber (Griffin & Co., Ltd., London), to which works the reader is referred for further information upon this subject.

The thickness of the rubber layer differs very much, sometimes we find a thickness of about $\frac{1}{40}$ of an inch (0·6 mm.) at other times twice this and even more. It may also occur that expensive hoses have a thin layer of rubber lining and cheaper qualities a thick lining. The user may then feel sure that in the cheap hose inferior rubber has been used which had to be applied in a thicker layer in order to give it the strength and tightness which is secured by a thinner layer in the case of first class rubber. Proof of this may be furnished by an elasticity test.

To the mixture of which the rubber lining is made a colouring material is often added. Rubber juice when obtained is light in colour, but is darkened by being coagulated in smoke. Rubber-lined hose has the advantage of being watertight, and, therefore, not causing any unnecessary damage by water, and owing to the smooth inner wall, the resistance which it offers to the flow of the water is much less than in the case of unlined hose.

This reduction of resistance applies in particular to long lengths of hose as will be seen from a comparison of the tables on pp. 104 and 106.

The rubber lining has no effect in strengthening the hose. It is the canvas fabric that has to be relied on to withstand the pressure: there is practically no strength in the rubber: indeed, in one sense the rubber-lining is detrimental to the strength of the hose, in that it prevents the water soaking into the canvas and thus strengthening it, and for this reason a hose for rubber-lining, to withstand the same pressure as a hose for use unlined, has to be made proportionately stronger. Good rubber-lined 2¾-inch hose is able to withstand a test pressure of 375 lbs. per square inch or 25 atmospheres without bursting. The usual test applied to a consignment is 300 lbs. for 10 per cent. and 150 lbs. the remainder.

Rubber-lined hose is considerable higher in price—if best quality materials are used the rubber-lined hose costs 2 to 3 times as much as the unlined—and great care is required in its upkeep, including running water through it fairly frequently, otherwise it becomes hard and cracks at the folds, and the hose, on account of the perishing of the rubber, will have a relatively short life. With proper care, however, it needs less repair and possesses greater durability. Well equipped fire brigades, therefore, ought to have hose of this class, in any case on the appliances used for the so-called first attack, such as the escape vans and hose trucks, to prevent damage by water when drawing it through rooms where there is no fire.

In small towns, country districts, and places where damage by water is of less importance, unlined hose should be used, as it occupies less space in the appliances and thus allows a larger number of lengths to be carried.

Fire Brigades which are unable to give proper and particular attention to the maintenance of their hose should not be supplied with lined hose.

The unlined hose has another advantage over the lined when in use, especially under the higher pressure of steam fire engines, sudden bursting

occurs less frequently and the hose by showing a leak gives previous warning. If unlined hose is seriously injured at any point it will develop a big leak there which will show either that the damage must be speedily attended to (by the use of hose bands or clamps, which will be referred to later) in order to prevent a burst, or that the hole is so serious that the hose must at once be replaced by another length. A lined hose, however, may be seriously injured externally without showing a leak as long as the rubber lining is still intact. At a given moment the damage attains such a character that the hose is no longer able to withstand the pressure and it suddenly bursts.

The flexibility of woven hose generally diminishes very much as soon as it gets wet, especially in the case of flax and hemp. If the hose is lined, the fabric is not wetted at any rate by water flowing through, and it, therefore, remains flexible so long as it does not get wet from outside.

The texture of the hose is liable to wear, owing to external injury caused by its being drawn over roads or pavements, falling on objects, getting scratched in the hose truck, etc., and by the action of moisture.

External injury can only be guarded against by proper care. The unnecessary dragging of hose over the road must be avoided; but during a fire, owing to the necessity for speed, it is not always possible to do this. Nevertheless it frequently occurs when making up the hose after a fire, care should be taken that it is not dragged about except in case of absolute necessity. The hose after being uncoupled should be rolled up as it lies and taken away in the coiled condition. If before they can be rolled up they must first be partly or wholly shifted, they must be dragged as little as possible and carried so far as practicable. Chafing in the hose box can be obviated to a great extent by care; the hose lengths should not be coiled up at random without any order, but should be placed in coils in proper order or flaked horizontally to fit the hose box; room should be allowed in the box for the hose being readily removed preferably from either side.

It is very doubtful if any advantage in wear can be proved by tanning or burnettising canvas hose in England, even if properly done. It certainly is not worth the expense usually charged.

It is claimed that tanning canvas hose is of a distinct benefit as a preservative for hose to be used in hot climates, and is a real preservative against rot and mildew. Also that "Burnettising" unlined hose renders it soft and pliable. It certainly does shrink the fabric before grit and dirt can get between the threads, and reduces the length to be paid for by quite 3 per cent.

Specification for unlined Hose.—The hose is to be manufactured in Great Britain; it is to be of the best long, clean flax, unlined, and equal in all respects to the sealed pattern kept at the chief station of the Fire Brigade.

The hose is to be free from flaws and defects of every kind, and is to be manufactured and delivered in lengths. Each length is not to exceed 102 feet or to be less than 98 feet in length.

The hose when finished is to have an internal diameter throughout of exactly $2\frac{3}{4}$ inches. Any hose which is found to vary $\frac{1}{16}$ inch from this diameter will be rejected. The flax fabric of the hose is to be plain hand or machine woven.

The hose is to be delivered free of charge to the chief station. The hose will be fitted with couplings, etc., by the Brigade.

The hose is to be in all respects to the approval of the Chief Officer who shall himself or by deputy be at all times at liberty to enter upon any workshop, factory, or place where any operations are being carried on under the Contract for the purpose of inspecting any hose in course of manufacture, or any material to be used in the manufacture, and of satisfying himself that the hose is being manufactured in accordance with this specification. The Chief Officer shall have power to reject any hose which in his judgment (which shall be final) is not in accordance with this specification. Each length will be tested to, and must withstand an internal pressure of, 300 lbs. upon the square inch without showing signs of undue leakage or material alteration in external diameter. The elongation under an internal pressure of 300 lbs. is not to exceed 5 per cent. Any hose which does not completely satisfy the test may be rejected.

Tenders will be considered from manufacturers for hose woven with more or less strands than in the specification or in the pattern hose, provided that it complies generally with the other conditions in the specification.

The War Office specifications have the following percolation test, which will be seen to be about the same as mentioned on p. 332, but it is doubtful if the extra driving of the yarn in the hose so closely together in the weaving does not tend to make the hose hard, stiff and inflexible after being in use a few times.

APPROXIMATE WEIGHTS OF DELIVERY HOSE PER FOOT RUN.

Inside Diameter.			kg.	lbs.
Inches.	mm.			
¾	19	Canvas lined.	·077	·17
¾	19	,, unlined.	·027	·06
¾	19	Leather.	·104	·23
1½	38	Canvas unlined.	·054	·12
1¾	44	,, ,,	·073	·16
2	51	,, ,,	·082	·18
2¼	57	Leather.	·340	·75
2¼	57	Canvas unlined.	·095	·21
2½	64	,, ,,	·104	·23
2¾	70	,, ,,	·127	·28
2¾	70	,, lined.	·227	·50
3	76	,, ,,	·254	·56
3	76	,, unlined.	·141	·31
3¼	83	,, ,,	·159	·35
3½	89	,, ,,	·163	·36
4	100	,, ,,	·181	·40
5	127	,, ,,	·227	·50
6	152	,, ,,	·272	·60

" Any or all lengths will be filled with water at a pressure of 95 to 100 lbs. per square inch, and allowed to stand for 10 minutes. The pressure will then be released and the hose allowed to remain limp for 5 minutes. The pressure will again be raised to 95 to 100 lbs. per square inch, and the

percolation measured. The percolation so measured must not exceed 1 fluid ounce in 5 feet length per minute.

"Should 10 per cent. of the hose fail to stand the tests, the whole delivery may be rejected without further test."

Suction Hose.—The early fire engines drew their water supply solely from the tanks formed in the body of the engine in which they were fixed. These tanks were charged with water from buckets handed from person to person forming a chain from the pond, river, pump, or other source of supply.

About 1677 Jan van der Heijden (who introduced leather delivery hose and was a maker of fire engines), arranged a large sized tube (see Figs. 168, 169) of linen joined at its upper end to a funnel shaped sack supported upon a frame, into which sack water was poured from buckets and later the funnel was supplied by a lift pump (see Fig. 169) thus dispensing with the number of people passing buckets. The water could only reach the fire engine where the supply was upon higher ground than the engines.

In 1698 Heijden made a further great improvement by the manufacture of a suction hose (see Figs. 168 and 169) by which the water could be drawn up direct to the pump, thus reducing the amount of labour required and also the loss of water by spilling.

It is of the utmost importance, in order to obtain the best results from any pump, to arrange that the water be delivered to the pump with as little obstruction to the flow as possible. Suctions are, therefore, made of such a size as will allow an abundant flow of water under small pressure to readily reach the base of the pump. The valves should have ample area and the section hose should be as large as can be conveniently carried.

The word suction is used to denote the action of the pump in causing a partial vacuum in the pipe; the result, as explained in Chapter I., is that the water rises and replaces the air withdrawn.

Theoretically the vertical height to which the atmospheric pressure will force the water to rise is 33·88 feet (1 atmosphere = 10,333 kilos. on the square metre). This is with the temperature of the water at 62° F. (16·6° C.), and the height of the barometer 30 inches (0·762 m.). Even under these conditions the water would only stand at that level, and would not flow into the pump.

As it is next to impossible to obtain a complete vacuum equal to 1 atmosphere, it must never be expected that a fire pump will draw water under the very best conditions more than a height of about 28 feet (8·5 m.). In fact, the nearer the pump to the level of the water, the better.

The best condition under which water can be drawn is when the level of the water supply is above that of the suction valves. This condition is known as "Drowned pump"

Many pumps fail through restricted flow of water to the valves; this may be through the holes in the strainer not having sufficient area in the aggregate, or having become partly blocked by some obstruction.

Suction strainers should be in proportion to the size of the pump, the old patterns for working from canvas dams were in the form of oblong metal boxes covered in at the top and bottom, and perforated with holes on both sides and one end, the couplings being at the other end. The holes are usually a quarter of an inch (0·006 m.) in diameter, and the number should be sufficient to give an aggregate area of *not less* than twice that of the coupling

in the suction pipe. As dams are not much used now the suction strainers are made cylindrical with holes all round and at one end, the coupling being at the other end. Water that contains any vegetable matter soon causes an obstruction in holes of the strainer, and thus not only reduces the efficiency of the pump, but some of the material may get under the valves, and thereby prevent any vacuum being obtained. Brigades who are liable to be called upon to work from ponds or ditches, etc., should carry an extra strainer in addition to the metal one. A plum-shaped basket about 24 inches (0·6 m.) in length and not less than twice the diameter of the outside of the suction pipe, with one end open as so to just allow the coupling to enter, answers well. It can be secured by straps. In every case where the lift exceeds 19 or 20 feet (5·8 or 6 m.) the metal strainer should be replaced by a foot

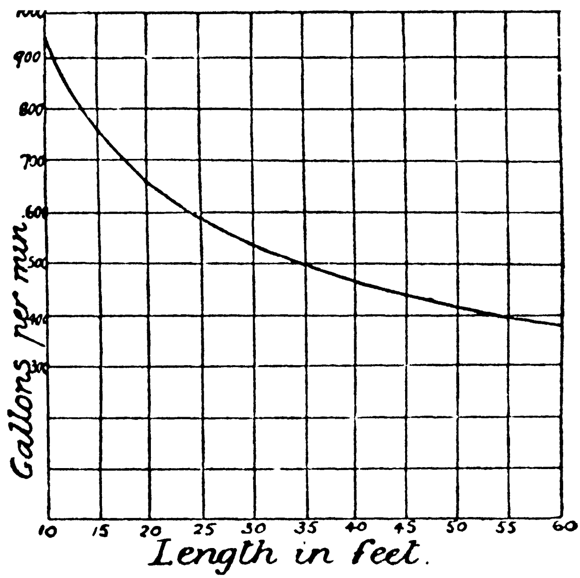


Fig. 205*d*.

valve which will allow the water to flow freely in, but not back; by this means the suction is kept charged when the pump stops, and ready to restart.

A new contrivance is to be obtained combining a suction strainer, small pump, and if desired, a foot valve, with a connection at the side to which a line of delivery hose from a pump or hydrant can be joined. By forcing water down the hose into the foot valve box a water wheel is actuated which drives the small pump and forces the water up the suction pipe. It is claimed that for short lifts three times the quantity of water passing down the hose is forced up the suction, of course the deeper the well the less water will be obtained. 115 gallons of water at pump pressure down the delivery is said to produce from a depth of 50 feet 250 gallons up the suction.

The length of suction pipe used is of the greatest importance, as the flow of the water is much retarded by the friction on the inside of the pipe when working from a pond or open water.

The diagram, Fig. 205*d*, will show at a glance how the number of gallons of water flowing through 3½-inch (0·09 m.), 4-inch (0·1 m.) and 5-inch (0·13 m.) suctions is reduced by each foot in length. This chart is theoretically drawn from figures deduced from Box's formula on the flow of water in straight iron pipes; in actual work the flows would be much further reduced by internal obstruction, bends, kinks, etc.

Many Brigades have discarded dams, and couple the suction direct to the hydrants, thus obtaining the advantage of any pressure in the mains and reducing the waste of water.

When the supply is from a hydrant direct to the pumps, and under pressure, the size of the suction can be less on account of the pressure in the water main, but this internal pressure must be taken into account in making this portion of the pipe. Suctions are usually made to withstand 1 atmosphere (14·7 lbs.) per square inch outside pressure, but many that will do so would burst if subjected to an internal pressure of 3 atmospheres or 44·1 lbs. on the square inch. Couplings must be well tied in or they may draw out of the pipe, where connected to a standpipe, particularly if used with a Steam Fire Engine that vibrates to any extent, or where the water pressure is intermittent, caused by hydrants being opened and closed quickly.

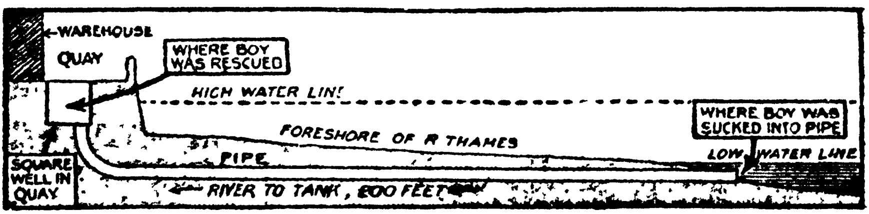


Fig 206.

This latter action will cause a "water hammer" and subject the system to temporary pressure far above the normal.

When a pressure as low as 14·7 lbs. per square inch is referred to as the maximum on the suction side of the pump, it must be remembered that it is *always in action* and ready to exert its force, as the following incident will show.

A boy, Percy Silk, 10 years of age, was pushed by a playmate into the Thames off Bankside, Southwark, in May, 1919, at low tide, and fell near the end of a suction pipe 3 feet (0·91 m.) in diameter, and 4 feet (1·22 m.) below the water level, used by the City of London Electric Lighting Company to draw water for condensing purposes, see Fig. 206, and as he disappeared a man who had noticed his disappearance from the shore warned the men at the power station that the boy had probably been sucked into the pipe. The water was immediately cut off and the officials rushed to the water-circulating chamber, 200 feet from the intake, expecting to find a dead body. One of them, while raising the iron grating over the well, called out; "Anybody there?" and was surprised by a lusty shout. Silk was found clinging to the top of a ladder, where he had climbed out of the water. Though wet and frightened, he was none the worse. The diagram, Fig. 206, will explain the power of 1 atmosphere.

It must be remembered that the strength of hose (suction or delivery) varies as the diameter, and therefore 3½-inch hose (0·09 m.) would stand a bursting pressure twice that of a 5-inch (0·13 m.) of the same thickness and quality.

A pinhole or a defective joint in a suction pipe, if the pipe is drawing water from an open pond or dam, will prevent a good vacuum being formed in the suction, with the result that the pump will receive a mixture of air and water, and develop a spluttering at the nozzle. This will break up the stream of water and render the jet ineffective. Should the leak be of any size, no vacuum will be formed and the pump will not be charged.

Suction Hose is made of Leather, Rubber, or Linen.

Leather suctions are made round a mandrel of the required size by first winding round galvanised iron wire of No. 6 B.W.G. (5·16 mm.). This is drawn out so as to allow 1½ inches (38 mm.) between each coil of the spiral, and the ends of the spiral are firmly soldered to the shanks of the screws. Stout canvas saturated with a mixture of boiling pitch and tar is then wound round the spiral; if this is expeditiously and properly done while the mixture is hot and every part covered with 4 thicknesses of the canvas it should be air-tight. An outer leather covering of light dressed kip with the grain outside is laid upon the canvas and temporarily secured. No. 12 B.W.G. (2·77 mm.) copper wire is then wound very tightly round the hose between the spirals, thus forming a corrugated surface.

Rubber suctions are made by wrapping alternate layers of canvas and rubber solution round the mandrel and spiral in a somewhat similar manner to that employed in the case of leather suctions, except that some are smooth upon the outside, and are vulcanised or cured in a chamber by steam under pressure at a temperature of about 293° F. (145° C.).

Linen suctions are made by twisting round the mandrel, linen coated with Stockholm tar or a composition similar to that given above as used for leather suctions, except that as many as 32 thicknesses of linen are used and there is no covering of leather or rubber, the outer layer being secured with galvanised steel wire rope between the spirals.

WEIGHTS OF SUCTION HOSE.

	Weight per foot (·3048 m.).		Couplings.		Usual Length.		Total weight.	
	lbs.	kg.	lbs.	kg.	feet	m.	lbs.	kg.
2-inch leather manual,	2·5	(1·13)	4·25	(1·9)	10·0	(3·0)	30	(13·6)
2½ " " "	2·8	(1·3)	4·5	(2·0)	6·5	(2·0)	22·7	(10·3)
					5·5	(1·7)	19·9	(9·0)
3½ " " steamer,	4·1	(1·9)	16·0	(7·3)	20·0	(6·1)	98	(44·5)
4½ " " "	5·7	(2·6)	25·0	(11·3)	20·0	(6·1)	139	(63·0)
4½ " rubber "	6·0	(2·7)	25·0	(11·3)	20·0	(6·1)	145	(65·8)
4½ " linen "	5·75	(2·6)	25·0	(11·3)	20·0	(6·1)	140	(63·5)
5 " leather "	7·5	(3·4)	28·0	(12·7)	20·0	(6·1)	178	(80·7)
5 " rubber "	8·4	(3·8)	28·0	(12·7)	20·0	(6·1)	196	(89·8)
5½ " " "	11·0	(5·0)	31·0	(14·1)	20·0	(6·1)	251	(113·9)

Suctions must be protected from injury caused by chafing and leather and wooden chocks are used when working on the level. If working from a dam or over a wall a pipe crutch of wood or iron is necessary to keep the strainer under water and prevent short bends.

Testing Steamer's Suctions.—Every steamer's suction should be tested not less than once in 3 months by means of a vacuum gauge.

Remove the strainer and replace it by a blank cap (fitted with a vacuum gauge), being careful to tighten the cap well down on to the washer.

Screw in the vacuum gauge, tightening it in the same manner.

Run the engine smartly for about 10 or 15 seconds. If a vacuum of from 22 to 27 inches is not quickly created, it is known that either the suction hose or the valves are defective. The exact amount of vacuum created will vary with different steamers, and also in the same steamer with changes in the barometer. After shutting the steamer off, the vacuum should be maintained for some minutes.

If the needle goes back quickly, take off the suction and put the blank cap on the inlet to the pump, and run the engine again. This time a vacuum of 22 to 27 inches should be created at once. If it is not, or if the pump will not hold the vacuum, then the valves are defective.

All lengths of suction should be tested, each length separately.

CHAPTER XII.

HAND APPLIANCES.

HAND appliances were naturally the first form of fire extinguisher, and even to this day remain the most important, if only from the fact, that by adopting domestic utensils a fair amount of protection may be obtained. No apology is necessary to again impress upon the reader that all fires were small at one time, and if it were always possible to promptly deal with them serious conflagrations would be avoided.

The earliest form of hand appliance, of which we have detailed account, appears in the writings of Hero of Alexandria. It is called a syringe. A translation from Hero's work by Bennet Woodcroft in 1851 gives the following description :—

"A hollow tube of some length is made (A B, Fig. 207), into this another tube, C D, is nicely fitted to the extremity C, of which is fastened a small plate or piston, and at D is a handle, E F. Cover the orifice A of the tube A B with a plate in which an extremely fine tube G H is fixed, its bore communicating with A B through the plate.

"When we desire to draw forth any pus we must apply the extreme orifice of the small tube H to the point in which the matter is, and draw the tube C D outwards by means of the handle. As a vacuum is thus produced in A B something else must enter to fill it, and as there is no other passage but through the mouth of the small tube, we shall of necessity draw up through this any fluid that may be near. Again, when we wish to inject any liquid, we place it in the tube A B, and taking hold of E F, depress the tube C D and force down the liquid until we think the injection is effected."

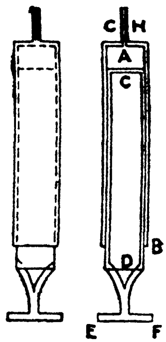


Fig. 207.

When Rome was being rebuilt after one of the serious fires orders were given that every citizen was to keep in his house "a machine for extinguishing fire."

Pliny mentions the use of "Siphos." Undoubtedly squirts or syringes were being used for fire extinction, and an abstract from a book by Apollodorus the architect to the Emperor Trajan, on how to act at a fire, is given on p. 329, Chap. XI. Undoubtedly the term "Sipho" was applied to an appliance for fire extinction. From all the best accounts this seems to have been in use in the fourth century, and it was called a "fire engine," and Milestus also mentions that they were in regular use in Constantinople for fire extinction and known as the "sipho."

It seems probable that, like many other useful articles, the Sipho or syringe was introduced into this country by the Romans during their occupation, and doubtless numbers were left when the Romans finally vacated these shores in 410 A.D., and furnished the pattern from which the London Squirts

of the seventeenth century were made. Several are still in existence, and one may be seen at the Vestry Hall, All Hallows, Lombard Street, London, removed from St. Dionis Church, Backchurch Lane, in the city of London,

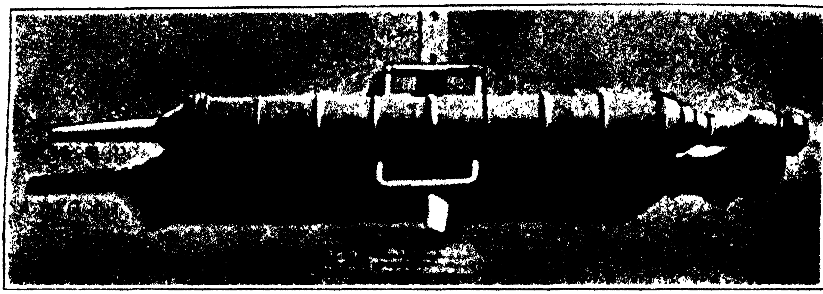


Fig. 208.

when it was pulled down. See Fig. 208, and compare it with the one described by Hero, Fig. 207.

A fire-extinguishing apparatus in a laboratory attached to a smelting furnace is mentioned in a book called "De Re Metallica" (Agricola), pub-

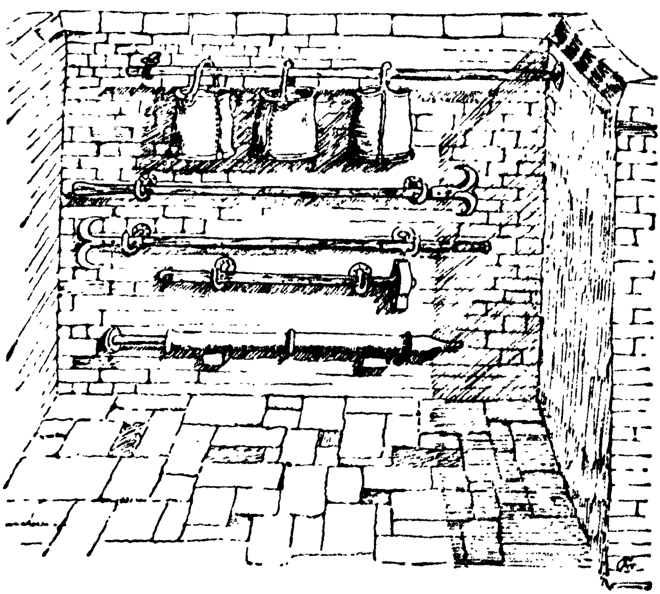


Fig. 209.

lished in 1546. The appliance is stated to have consisted of a sipho, a sledge hammer, two fire hooks hung upon hooks fixed into the wall, and three leather buckets suspended from the roof by an iron rod and rope (see Fig. 209).

Fig. 210 is a print of Lucar's engine from Besson's "Instrumentorum," French edition, 1578.

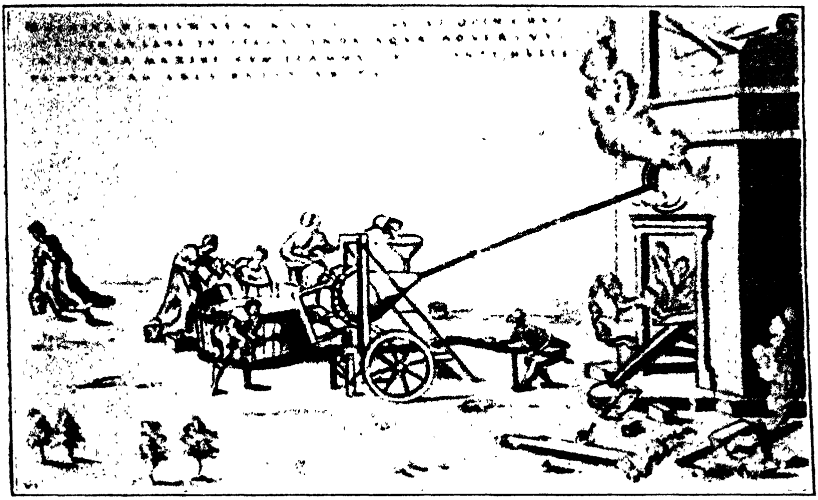


Fig. 210.

Fig. 211 shows the arrangement of the fire apparatus in the lobby of a modern Technical School. Upon the left is seen part of the smoke screen

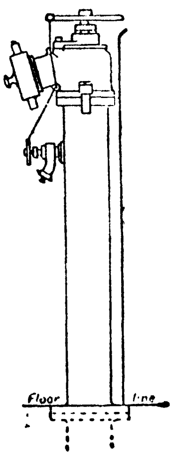


Fig. 211. Fig. 212.

erected to divide the staircase from the lobby; the screen is made of teak, with the upper panels glazed with fire-resisting glass. Fig. 212 shows a

post hydrant suitable for use in a building where the water main cannot be built in the wall.

Adapters.—See Connecting Screws.

Axe, Small or Fireman's.—The best form is made in the shape of a tomahawk. The head should be of faggotted wrought iron, 7½ inches (0·19 m.) long, steeled and tempered at the cutting edge and the curved point; the head is made with two clamps, 6 inches (0·15 m.) long and 1¼ inches (0·032 m.) wide. The handle should be 15 inches (0·38 m.) long and about 1¼ inches (0·32 m.) square with the angles rounded off except at the bottom. The weight is 1¾ lbs. (0·8 kg.), see Fig. 213. The earlier pattern is shown in Fig. 214.

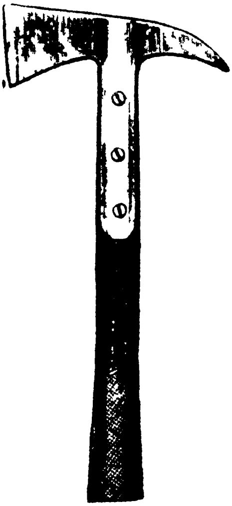


Fig. 213.

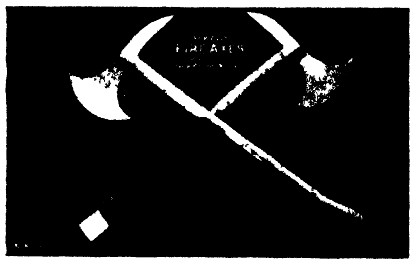


Fig. 214.

Blankets and Protection of Clothing.—Blankets and cloth steeped in water or a weak solution of alum or other antipyrene should always be kept close at hand upon the stages of theatres and other places where flimsy clothing is worn.

So many dangerous cases of fire have occurred in clothing that, for certain purposes and in certain works, the fireproofing of garments is advisable and necessary. Workmen engaged in the vicinity of sources of considerable heat (boiler fires, glass furnaces, pottery kilns, foundries, limekilns, etc.) should wear tight-fitting clothes, so that no loose flapping portions may come in contact with the fire. When garments are exposed to protracted heat they become thoroughly desiccated and, therefore, brittle, in which condition the fabric readily chars and is then ignited by the merest spark.

This danger is greatly increased when the garments become greasy from any cause; in such event the risk of spontaneous ignition is imminent, more especially if the men are working in a dusty atmosphere of any kind whatsoever (from coal, flour, cork, wood, fibres, fabrics, rags, or even metals), such dust, in conjunction with the fat, imparting pyrophorous tendencies to the clothes and rendering them liable to take fire spontaneously.

Cases have indeed been known where such clothes have ignited spontaneously when hanging up undisturbed, hence it is essential to provide fireproof clothing for workers engaged in establishments where danger is liable to arise from the presence of fat and dust simultaneously. In such event—as indeed with all porous materials—the uninflammability, to be of any value, must not solely be confined to the surface of the goods, but extend to the core of every individual fibre. True, the expensive process of fireproofing may be dispensed with if the garments be beaten daily and washed at intervals ; but it is difficult to ensure this being regularly done.

The garments, whether made flame-proof or not, should never be hung up near any source of heat, or packed tightly in any confined space.

The sparking or short-circuiting of electric wires, etc., may be a source of danger to clothes, if the latter carry any metallic fittings or trimmings (metallic tinsel on ballet costumes), or are impregnated with chlorates, nitrates, picrates, or fulminates ; special danger in this connection is incurred in breaking electric circuits, starting and stopping electrically driven machinery, etc. The arms, in particular, should be protected by rubber sleeves or mantles.

Textile fabrics (not wool) can be treated with various chemicals of a fire-resisting character, notably a solution of Stannate of Soda at 42° Tw., and subsequently in another solution of Ammonium Sulphate at 14° Tw. The British Fire Prevention Committee carried out a series of exhaustive tests with materials so treated with most satisfactory results ; see Red Book, No. 148. The Committee had the satisfaction at a little later date of prevailing upon the makers of a flannelette so treated to present their patents to the nation, whereby the possibility of any monopoly created by any one firm retaining the exclusive use of this beneficial invention has been most satisfactorily overcome.

Most other treatments are not so satisfactory, in that materials have to be re-impregnated at very frequent intervals.

Branch or Play Pipes are of various kinds. The rigid and semi-rigid types should not be more than 12 inches (0·3 m.) or 14 inches (0·36 m.) in length, and for general fire brigade work they are made at the large end to take a female coupling of the pattern used by the brigade. The smaller end is usually 1½ inches (0·038 m.) in diameter, and if carefully finished off, and the edge of the metal kept sharp, answers as a good 1½-inch (0·038 m.) nozzle. The weight of a copper branch with half-coupling at one end and brass boss at the other is about 5½ lbs. (2·5 kg.).

Short semi-rigid branches are made of rubber, flexible metallic tubing, and spiral tubing, covered with canvas, rope, etc., to give a good hand-hold. Some brigades prefer long flexible branches, which are simply an 8-feet (2·4 m.) or 10-feet (3 m.) length of leather or canvas hose made the full size at the base to take the male-hose coupling and gradually reduced to the size of the gunmetal boss at the other end. The size and make of the boss for the smaller end of the branch is important, as unless they are strictly to gauge the nozzle will not fit. As mentioned, the inside of the smaller boss should act as a 1½-inch (0·38 m.) nozzle, and if it is to be attached to a metal branch should be bored out to match the taper of the shaft to which it is brazed. In the case of the longer flexible branches the lower part of the boss is continued in the form of a serrated shank 2¾ inches (0·07 m.) in length,

for the purpose of securing the leather of the branch to it on the outside. The upper end of all bosses should be precisely similar, and the screwed part 1⅛ inches (0·03 m.) in height; part of this is taken up by a leather washer.

The weight of a 10-feet (3 m.) leather branch without nozzle is about 15½ lbs. (7 kg.).

Branches are also made with spreaders of various kinds. In some patterns the water can be entirely shut off by the man in charge, and this gives the opportunity of saving much water damage. The closing-down of the jet must never be done if the hose is attached to a reciprocating pump, and should be done fairly gradually when the line of hose is connected to a hydrant or centrifugal pump, otherwise a water hammer effect will be produced, and possibly a burst length of hose will result.

A reciprocating pump when at work must force the water somewhere or the pump will be brought to a standstill, whilst in the case of a centrifugal pump the water can be churned in the pump casing.

Sprays for spreading water over a large surface, such as the walls or furniture of a room, can be made by (1) placing the thumb over the jet, (2) deflecting the water by a metal plate or a spreading nozzle (in which the jet is split up by forcing a number of gunmetal bevelled plates fitted in a shield in front of the jet), or (3), better still, by the use of a hand-control branch. This hand-controlled branch consists of a short branch of aluminium, the lower end of which is formed to suit the coupling used by the brigade; in the centre is a cock to shut off the water, whilst the upper end is fitted with a gunmetal screw for the nozzle, and a collar arrangement for opening a spray. Upon unscrewing the collar a spray of water is allowed to emerge at any desired angle from nearly forward to about 50 degrees from the line of the jet; this forms a good water screen for the fireman with the branch.

The spray can be used with good effect in creating a draught for the removal of smoke or heated air.

Branch Holders.—Straps to fix round the base of a branch with two loops are useful, as they allow handhold for two men in cases where the position of the branch has to be continually moved.

Holders are especially useful for the direction of large jets, and in cases of high pressure where the back thrust is considerable and a branch cannot conveniently be lashed.

Care must be taken when using these holders to keep the heel of the stay secure, as should the branch get loose and take charge severe damage is readily caused to anyone in the way.

Branch Tallies.—Small straps with brass numbers are used in large brigades where many branches are often at work, to readily ascertain the number of the engine to which the line of hose is attached.

Radial Branches are constructed to allow a jet of water to be directed in any direction. Monitors upon fire floats are so fitted that large jets can be actuated by hand-wheels over a very wide range in any direction by one man. Great care is required in the construction of these branches in order to avoid sharp curves, which seriously break up the water and affect the stream thrown from the jet. When made in small sizes they are suitable for mounting upon a fire-brigade vehicle to form a portable water monitor. Long ladders can also have this type of branch fitted at the head for use

as a water tower, and thus project a horizontal stream of water into openings some distance above the ground. The direction of the jet can be controlled by a fireman upon the ladder or worked from the ground if fitted with gearing and ropes. Working from the ground has the advantage of allowing the jet to be brought close up to, and into the heat and smoke from, the fire. Great care is required in all cases that the pressure acting at the back of the nozzle is kept in proportion to the length of the ladder and the angle at which the jet is being worked, or the ladder will be thrown over backwards.

Breechings are for dividing or connecting streams of water in hose.

Brigades that use two sizes of hose run a large size, even up to 6 inches (0·15 m.), from the pump or hydrant to the fire, and then by means of a dividing breeching, which can be a metal box fitted with valves, separate the water into two or more lines of smaller hose. It is claimed that greater efficiency and much saving of time results by employing this contrivance, as a man posted at the breeching can attend to and turn off and on the water supply of the smaller lines of hose whilst within call of the men at the fire.

Most engines carry cast gunmetal connecting breechings, two into one and a one into two. These couplings, which must fit the hose, are made up by the junction of two male and one female couplings or one male and two female, the angle of the discharge side is about 45°, and the weight about 9 lbs. (4·1 kg.) each.

Firemen should understand the great saving of friction that is effected by using two lines of hose from the pump to the fire and joining them with a connecting breeching. See Chap. III.

Suction Breechings are not often required, as pump suctions should always be, if anything, larger than that theoretically required. In towns using large engines that depend upon the hydrants in the streets for their water supply, it may be found necessary to employ a metal case or breeching with several inlets. Each of the inlets should have couplings to fit the ordinary hose from the hydrants. As the pressure of water from separate hydrants is never the same, it is usual to provide each of the inlets with a flap valve, to prevent water being forced, by the pressure from one hydrant, through the breeching down another length.

The supply from each hydrant is thus forced into the breeching, as the pump tends to cause a vacuum.

Buckets.—The early types of buckets used for fire extinction were made of hides of leather sewn at the seams, and with the least amount of care would last a long time (Fig. 215).

As, however, there was a tendency for this bucket to kink at the base, a superior article was designed to overcome this defect by rivetting the seams and introducing a metal band to assist the leather to retain its shape. The buckets should be painted, the outside a dark colour, and the inside white; with ordinary care they will last a very long time. Necessarily, however, they occupy a considerable amount of space, and, therefore, had in turn to give way to the canvas bucket (Fig. 216).

This was adopted on account of its lightness and portability. The usual pattern is 8½ inches (0·22 m.) diameter and 12 inches (0·31 m.) deep. Only the best hemp duck or canvas should be used. The top and bottom having cane hoops let in and strongly sewn round to keep the bucket in shape. The handle is usually formed by a double strip of duck, 13 inches (0·33 m.)

long and 1¼ inches (0·038 m.) wide, attached to the upper hoop at each side. The centre of the handle is stiffened by a piece of wood 6 inches (0·152 m.) long and 1 inch (0·025 m.) wide, ½ inch (0 013 m) thick. The

Fig. 215.

Canvas Bucket Folded.

Fig. 216.

Fig. 217 —Self-opening Covered Fire Bucket.

bottom is then strengthened on the outside by two crossed cotton lines. Canvas buckets can be packed in a small space by slightly twisting and pressing the upper and lower hoops together, and then they occupy a space 9 inches (0·23 m.) in diameter and 1 inch (0·025 m.) in depth.

A canvas bucket as above described weighs when dry about $\frac{3}{4}$ lb. (0·34 kg.), and will hold about $2\frac{1}{2}$ gallons (11·35 l.). At least a nest of six of these canvas buckets should be carried upon each fire appliance, as the space occupied is small, and the weight including the strap is under 5 lbs. (2·27 kg.).

In order to prevent the defilement and evaporation of the water when buckets have been standing any length of time, especially in mills and places where the atmosphere contains a large amount of suspended matter, covers can be provided hinged and so attached that they open automatically when the handle is tilted by the action of throwing the water (Fig. 217).

Buckets for first-aid work should always be kept in a permanent position, and at the same time placed so as not to obstruct free movement along corridors and staircases. When hung on brackets they should be in such

Fig. 218.

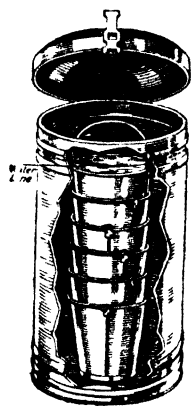


Fig. 219.

Fig. 220.

positions as not to obstruct the headway, and yet allow an ordinary-sized person to get them down without spilling the water.

It is frequently found difficult to keep buckets in their proper places, as they are very liable to be removed for other purposes, and for this reason buckets with rounded bottoms have been introduced (Fig. 218).

They have, however, this disadvantage, that as they will not stand upright by themselves, it is impossible for a person carrying more than one to open a door or to throw water without first carefully setting down one of the pails in a corner.

Another convenient method of storing buckets of water ready for immediate use is by means of iron tanks (Fig. 219).

The buckets being telescopically packed in the tank, which is filled with water, so that when required the buckets are filled as they are drawn out. These tanks can be made to contain twenty buckets and the necessary water. In practice it has been found that nests of ten make a more

convenient arrangement, and if a larger number is required a second tank should be provided.

Sealed Fire Pails are constructed in more complicated patterns, such as shown in Fig. 220. These buckets are made to contain 3 gallons (13·6 l.), but this particular shape cannot be emptied at a single throw. The lid is so formed that it may be sealed by wax and yet be easily removed. The lid being tight, prevents the evaporation or pollution of the contents.

Common salt may be added to the water in Fire Appliances to prevent freezing in moderately cold temperatures. Too much salt should not be used, as it causes rust, the more concentrated the solution the greater the tendency of the solution to "creep" and crystallise upon the outside of the buckets.

The following table has been given to indicate the freezing points of solutions of salt :—

Percentage of Salt to Water by Weight.	Freezing Point, Degrees.	
	Fahrenheit.	Centigrade.
1 per cent. salt, ...	32	0
5 " "	25	— 3·8
10 " "	19	— 7·2
15 " "	12	—11·1
20 " "	7	—13·8
25 " "	1	—17·2

Calcium Chloride is a solid substance like common salt, and can be used with water as a non-freezing solution. It differs from salt in that it will not "creep" and crystallise over the receptacle. The amount necessary to make a saturated solution decreases with the temperature of the solution, so that the calcium in a saturated solution of 60° F. will, as the temperature falls, crystallise out and float on the surface of the water in the form of a film and may collect dust, but even then it is preferable to salt, which crystallises under most conditions. It does not rust metal, but will slightly attack solder, moreover it is not suitable for use in chemical extinguishers, as it prevents the desired chemical action between the ingredients usually employed in these appliances. This does not apply to appliances in which compressed carbonic acid gas or compressed air is used to eject water.

FREEZING POINTS OF CALCIUM CHLORIDE.

Pounds per Gallon of Water.	Temperature of Freezing.		Pounds per Gallon of Water.	Temperature of Freezing.	
	Fahrenheit.	Centigrade.		Fahrenheit.	Centigrade.
½	+29	— 1·6	3½	— 8 to 11	—22
1	27	— 2·7	4	—17 to 19	—27
1½	23	— 5	4½	—27 to 29	—34
2	18	— 7·7	5	—39 to 41	—40
2½	3 to 4	—16	5½	—50 to 54	—47
3	—1 to 4	—17			

Canvas Chutes.—See Jumping Sheet.

Cellar Pipes are of several patterns, designed for fires in cellars and basements, and can be used between the roof and ceiling joists of a building. A hole is cut through the floor and the pipe inserted, at the end of which is a nozzle which can be turned in any direction and raised or lowered by actuating a spindle from the floor above.

Chair-Knots.—See Figs. 250 and 251.

Chemical Fire Extinguishers.—In 1816 a Captain Manby invented an apparatus consisting of a cylindrical copper vessel 24 inches (0·61 m.) long and 8 inches (0·203 m.) in diameter, holding over 4 gallons (18·16 l.), and fitted with a ¼-inch (0·0063 m.) internal pipe joined up to a cock to which a jet pipe ⅛ inch (0·0031 m.) in diameter was attached. The charge was 3 gallons (13·62 l.) of water, in which carbonate of potash (pearlash) had been dissolved. The remaining space in the cylinder was then filled with compressed air through the cock by means of a pump, and on the jet being replaced it was ready for action.

Single cylinders were conveyed on men's backs by straps, but sets of six connected to a jet pipe were transported in a hand cart.

Since Captain Manby's time many devices have been produced to provide a handy means of attacking incipient fires. Much mystery has been made by inventors of the nature of the chemicals used. Many schemes have come to naught. The use of carbonic acid gas with water contained in a cylinder of moderate size has provided a valuable fire appliance. These extinguishers are not only of great use to the general public, but are found invaluable to firemen, and should always be carried upon the appliances.

The production of the carbonic acid gas in sufficient quantities to cause the water to be projected from the container with some force has been the aim of many inventors, each claiming that his device is the best. During the last few years persistent endeavours have been made to standardise these extinguishers, and in 1913 the British Fire Prevention Committee published "Red Book," No. 168, in which a specification for the construction of extinguishers was given, and further notes, etc., are set out in "Red Book," No. 235, March, 1919, from which the general chemical and physical principles mostly employed in portable extinguishers can be obtained.

The original requirements of the British Fire Prevention Committee, given in a Specification for the construction of Liquid Chemical Fire Extinguishers have formed the base upon which other Authorities have worked.

Specifications are now issued by

- The British Fire Prevention Committee,
- The Board of Trade,
- H.M. Office of Works,
- Metropolitan Police,
- The Fire Offices Committee for insured property,
- The National Board of Fire Underwriters,

and now in a modified form by the British Engineering Standards Association.

Purchasers of these appliances should see that any they buy conform to one of the above specifications.

Chisel, Cold, made of octagon bar steel 8 inches (0·2 m.) long and about ¾ of an inch (0·02 m.) in diameter, with a chisel end, is useful; weight, say, 1 lb. (0·45 kg.).

Connecting Screws should be carried to fit the hose used by all neighbouring brigades.

Crowbar, 3 feet (0·91 m.) long, 1 inch (0·03 m.) thick, wrought iron, chisel-shaped at one end and pointed at the other; weight, 10½ lbs. (4·8 kg.).

Dams, or Portable Cisterns, are not often used nowadays, except where the water has to be pumped long distances or up to great heights. The pattern carried upon engines is formed of a frame of ¾-inch (0·02 m.) galvanised iron gas tubing top and bottom, joined by knuckle-jointed gunmetal uprights. The whole covered with strong sail canvas with leather binding and straps.

For Manual Engines the frames are 32 inches (0·81 m.) by 15 inches (0·38 m.) by 18 inches (0·46 m.) deep, and weigh complete 35 lbs. (15·9 kg.).

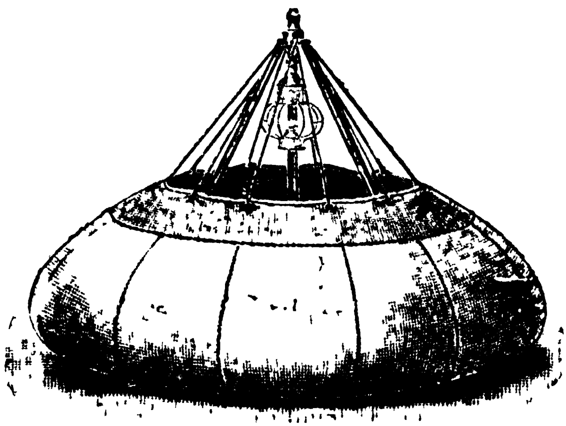


Fig. 221.—Large Circular Dam supported by Tripod.

A Steamer Dam is 36 inches (0·91 m.) by 18 inches (0·46 m.) by 18 inches (0·46 m.) deep, and weighs 45 lbs. (20·4 kg.).

Large dams or canvas tanks can be made of 12 pieces of timber, 8 iron cross-stays, and lined with canvas. A dam 8 feet (2·44 m.) long, 6 feet (1·83 m.) wide, and 3½ feet (1·07 m.) deep (and as the canvas sags) will hold nearly 900 gallons (4,087 l.), and weigh about 500 lbs. (227 kg.) empty, and when filled with water 4½ tons (4,572 kg.).

Circular canvas cisterns supported by a tripod inside the canvas and holding 700 gallons (3,179 l.) are used by some brigades; they are quickly set up and occupy a comparatively small space (see Fig. 221).

Fire Hook or Preventor is similar to a boat-hook, the head of wrought iron 17 inches (0·43 m.) long, ends with a spike 5 inches (0·13 m.) long, and ½ inch (0·013 m.) thick at its junction with another spike of the same length set at right angle; this is also ½ inch (0·013 m.) thick, but the lower side is made into a cutting edge. In the lower part of the head the iron is formed into a tapered socket and strap for fixing upon an ash handle 8 feet

(2·44 m.) long. It is a very useful implement for doing all kinds of work out of reach of firemen's hands, and especially for pricking ceilings to allow water to get away. Weight of complete preventor, 6 lbs. (2·3 kg.).

Dry Powder as a fire extinguisher was much boomed in the early part of this century, and through the dexterity of the demonstrators in extinguishing surface fires, created a ready sale. On the 30th March, 1916, the Secretary of State for the Home Department appointed a Committee to conduct experiments to test the value of dry powder fire extinguishers as compared with water and other "first-aid" appliances. The Committee reported on 27th April, 1916, and in conclusion were "confident that by far the best extinguishing agent is a plentiful supply of water applied in the manner most convenient, and that the use of dry powder extinguishers is to be deprecated as, not only giving a misleading sense of security, but being practically useless for extinguishing or effectively controlling fires likely to be caused by bombs."

Fire Escapes.—See Ladders.

Fire Screen.—See Screen Fire.

Foam.—The extended use of internal combustion engines has caused a large increase in the number of places at which petrol and light oils are kept. The attendant danger from fire in and about petrol stores is dealt with by the regulations of the local authorities (see Chap. IV.).

These light oils are difficult to extinguish by the aid of water alone. Attention has, therefore, been turned to perfecting some means of smothering the burning liquid, especially in ships, boats, and other enclosed places. At first the small-sized extinguishers, somewhat modified in form, were used to contain the liquids required to produce a large quantity of foam.

The effect of a thick coat of foam to deprive the surface of the unconsumed oil of any oxygen has been amply demonstrated. Appliances, small for hand manipulation and large for fixed installations, have been constructed, with so far satisfactory results.

The small sizes are operated in a similar manner to the ordinary chemical extinguishers, the 2 gallons of the special ingredients forming approximately 4 to 6 times their volume of foam.

As regards the large fixed installations, only a few have as yet been erected in this country, but a considerable number have been installed abroad, and the experience obtained from these in actual fires has on the whole been quite good. The modern "tank farm"—that is, storage ground on which a number of tanks have been erected each with a capacity running from 500,000 to 2,000,000 gallons of oil or petroleum spirit—demands careful consideration, and the fire offices have drawn up special rules for foam installations at these risks. The chief rule is that there should be 4 imperial gallons of each of the chemical solutions to each square foot of area likely to be subjected to one fire.

The ingredients necessary to make a good foam are set forth in the Appendix.

Foam installations are now provided in many forms, the apparatus necessary for its use in large quantities may consist of a tank or tanks containing the chemicals and the means of ejecting the solution, which may be by a charge of carbonic acid gas similar to that used in fire extinguishers.

Another system is to have the chemicals stored in a dry state in tanks. When they are required a line of hose is connected with an inlet and water forced through the tank and out by another line of hose. During the passage of the water through the tank the chemicals and water are mixed and pass out of the tank in the form of foam. The distance the foam can be thrown is governed by the pressure in, and the size of, the supply pipes. Much depends upon the tenacity of the Foam. Liquorice is used as a stiffener.

Hand Grenades.—Zachary Greyl in 1721 at Dresden demonstrated before the King of Poland in public how fires could be extinguished by chemical action.

Ambrose Godfrey, of Covent Garden, a pupil of the renowned chemist, Robert Boyle, achieved great notoriety in making phosphorus which he called Phosphorus Glacialis. During 40 years he developed a large trade in this substance, especially on the Continent. Hence the substance became to be known as English Phosphorus. He also developed a method for extinguishing fires by what he called a water bomb. He observed that there always appeared great difficulty in bringing the ordinary water engine in use in that day near to the scene of a fire owing to the narrow thoroughfares, and also that invariably when access was obtained only the front of a building could be attacked, and the rear was nearly always reduced to ashes.

The water bomb was designed to overcome that objection, and consisted of a pewter vessel filled with gunpowder placed inside a barrel suitably lined to contain water without leaking. The barrel was filled with water and sal ammoniac, and from the head of the barrel a fuze was connected to the gunpowder in the pewter canister. The fuse was lighted and the whole contrivance thrown bodily into the burning building at the upper storey. The barrel would, of course, be blown to pieces by the explosion of the gunpowder and the water scattered over the burning building. Demonstrations were given on 2nd April, 1723, at Belsize Park, Hampstead, before the Lord High Chancellor and many other notabilities, and again on 30th May, 1723, in Westminster Fields in the presence of a multitude. The first demonstration was only a partial success, as the bomb was thrown first into the ground floor instead of through the upper window. The bombs were made by W. Brigges, Joiner, in Salisbury Street, Strand, at prices ranging in five grades from one shilling and fivepence to seven shillings and sixpence.

Hand Grenades were sold in large numbers a few years ago, and may still be seen in suspended wire cages in private buildings.

The principal value claimed by the venders of these articles was that they gave off carbonic acid gas in sufficient quantities to subdue any reasonably small fire in an enclosed space. In the early part of 1914 a fire occurred in an enclosed brick store in the basement of the Sayer Street School, New Kent Road, London; the whole of the contents was burnt, and after the fire was extinguished a cage with two broken grenades was found hanging upon the wall.

Hand Pump.—The most simple apparatus now in use is the hand pump (Fig. 222), which consists of two pieces of brass tubing 2¼ inches (0·06 m.) and 1¼ inches (0·03 m.) in diameter respectively. The central one being fitted with a wrought-iron piston rod ⅝ inch (0·016 m.) in diameter, which

is attached to a handle. The bottom of the outer tube is fitted with gun-metal suction valve box, which is perforated with some 24 small holes $\frac{1}{16}$ inch (0·002 m.) in diameter. By placing the outlet to the hose about 3 inches (0·08 m.) from the bottom, the upper portion of the larger cylinder forms an air chamber. The stroke of the piston is 11 inches (0·28 m.), and being $1\frac{1}{4}$ inches (0·03 m.) in diameter, gives a capacity of about $13\frac{1}{2}$ cubic inches, or $\frac{1}{20}$ of a gallon (0·23 l.). Therefore, 20 strokes would discharge with an open delivery 1 gallon (4·5 l.). It is considered that a man can work a pump of this kind for some time at the rate of 100 strokes per minute. The pumps are usually fitted with two 10-feet (0·34 m.) lengths of hose $\frac{3}{4}$ inch (0·022 m.) in diameter. This hose may be either leather, rubber, canvas, or canvas

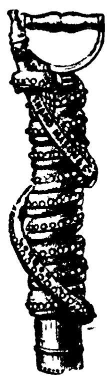


Fig. 222 —Hand Pump with Hose and Jet

Fig. 223.

rubber-lined. The couplings usually have a $\frac{3}{4}$-inch (0·02 m.) waterway, and the jet used is $\frac{3}{16}$ inch (0·005 m.).

A larger hand pump known as the "Tozer" is much favoured by many firemen, particularly where strong men are available to actuate them; they can be worked by two persons, and give a powerful jet that can be made to reach nearly 50 feet (15·2 m.) in height. They are constructed upon similar lines to the small one, but the upper part is enlarged to allow more air space. The large hand pumps, if not fitted in cisterns, require some form of foot plate, so that the person working the pump may apply his energy to the best advantage. The smaller pattern should also be fitted with a stirrup in which the foot can be placed, thus leaving both hands free (see Fig. 223).

The outlet is best fitted at the lower end of the outer cylinder, as explained above, and shown in Fig. 222. Some pumps, however, have the outlet

at the upper end, in order to allow an easier fitting to be made when it is desired to use them in connection with cisterns or collapsible canvas buckets (Fig. 224).

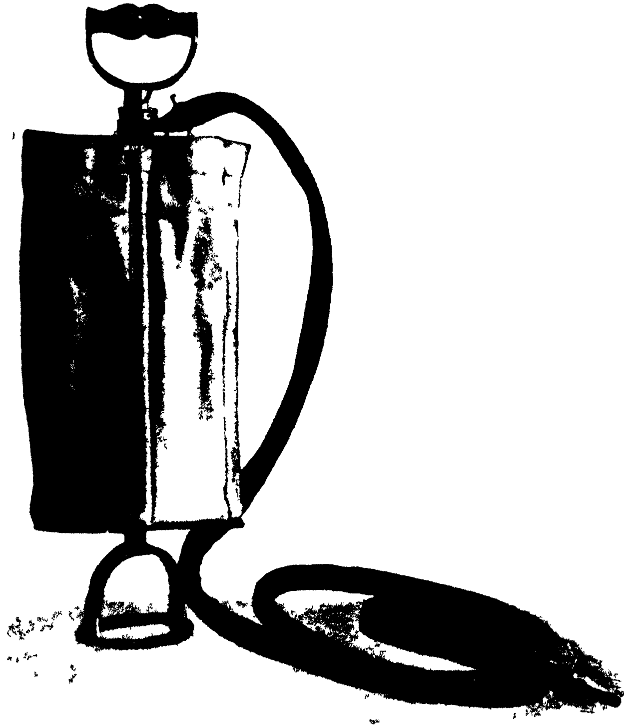


Fig 224

Hook Ladders.—See Ladders.

Hose Ramps.—These are to protect fire hose when laid in carriageways from damage by the wheels of vehicles, and can be made in various ways.

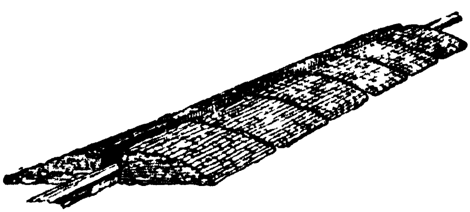


Fig 225.

Some brigades use mats made of and filled with rushes. The mats are some 24 inches (0·6 m.) square, and slope from the road surface to a height of twice the diameter of the hose. They are placed side by side (see Fig. 225).

Others use bevelled wooden blocks, hinged by iron at the ground level, the width of the cavity being equal to the diameter of the hose, the blocks are usually 9 inches (0·23 m.) wide.

A more elaborate form is shown in Fig. 226, constructed of hard wood blocks, 8 inches (0·2 m.) wide, fixed upon strong leather bases with rope, and the corners secured with hoop-iron straps.

To allow trams to continue running, heavy iron rails from 6 to 10 feet (1·8 to 3 m.) long are used, these have hinged rails, 2 feet (0·6 m.) in length at either end, and bevelled down to a feather-edge for fixing upon the tram lines. Slots are cut on the underside of the rails for the passage of the hose, cars apparently run over these little bridges without any difficulty. These ramps could not be used with the conduit system.

Hose Saddles.—These can be made of wood or metal, and are used to protect hose when upon a wall or fence; they should be fitted with projecting spikes on either side to prevent the saddle slipping over the wall, and a strap to keep the hose in the channel (see Fig. 227).

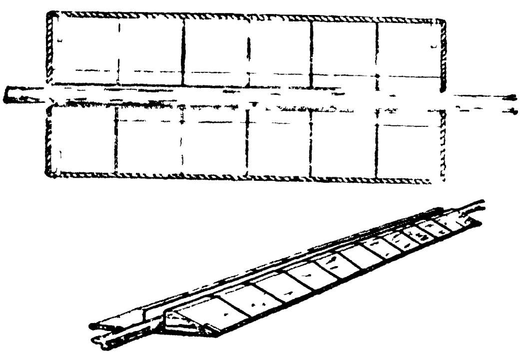


Fig. 226.

Fig. 227.

Hydrant Keys or Turncock's Tools should be carried upon each appliance, and care taken that they are not subject to undue force, or damaged in any way, particularly the socket that fits over the spindle on the hydrants.

The square end of the spindles upon the hydrants should all be of one size, and as far as possible brought up to a level just under the iron hydrant cover.

Jumping Sheets and Nets.—Jumping sheets are made in two patterns, (*a*) 10 feet (3 m.) square, with the seams strengthened underneath with webbing and fitted with 32 rope handles, weight about 29 lbs. (13 kg.); (*b*) circular 10 feet (3 m.) in diameter, with an area of about 80 square feet (74 m.^{2}), made of radial lengths of strong No. 1 sail canvas, with seams strengthened underneath by webbing, 24 handles round the edge, weight about 32 lbs. (14·5 kg.).

Circular Net.—These are usually made 10 feet (3 m.) in diameter of best Russian hemp rope with a stout rope round the edges to form a good hand-hold for a large number of helpers. The weight is about 35 lbs. (16 kg.).

Some brigades have jumping nets fitted with metal springs and other

gadgets, but these add to the weight and require extra space for storage in the appliances.

It must be remembered that *all* buildings should be so constructed that the inmates have proper means of leaving without resource to jumping from windows, and firemen on arrival should have with them ladders, etc., to rescue any person whose escape has been cut off from the provided exits.

It may be taken for granted that a person jumping from a building at a fire will be injured, or some of the assistants holding the sheet seriously hurt.

Canvas tubes are still to be found in some buildings, placed there as a make-shift, and as an excuse of the owners of the property to save themselves the expense of providing proper means of exit by staircase. These chutes after a period of time are found to be in the way of the occupiers, and are consigned to any out-of-the-way corner, and the canvas is often found to be untrustworthy owing to damp and mildew. Fatalities have occurred by persons becoming jammed during descent, and burnt by fire issuing from a lower window ; also a nail in a shoe has cut a hole in the canvas sufficiently large to allow the person to fall through on to the pavement and be killed.

In Central Europe canvas chutes have been used in the form of sheets from 8 feet 6 inches (2·5 m.) to 10 feet (3 m.) in width, and of sufficient length to reach the highest windows. The upper end is fitted with a stout pole the full width of the chute, which allows the canvas to be kept close to the wall of the building and project well upon either side of the window. The lower end is kept above the ground by fireman and assistants holding the sides of the canvas, or when the full length is required by ropes attached to the end. This pole with the canvas attached has to be hauled up to the window and properly secured, and this occupies time. As persons may be despatched with only short intervals, it is claimed that 40 persons per minute can be sent down with safety.

Many, more or less, ingenious contrivances have been suggested as a means of rescuing persons from burning buildings. It would not be helpful to ennumerate all the ideas, but one might be mentioned in passing.

In the passage near the large kitchen at Hampton Court Palace are to be seen two long poles lying upon brackets. One of these, 48 feet (14·6 m.) long, is provided with a wooden wheel at the top, and a large spike at the lower end to fix into the ground. The upper end has two iron arms splayed out, so that the pole when erected would rest with its head about 14 inches (0·36 m.) away from the wall and allow a rope to pass over the wheel by which an iron collar could be worked up and down the shaft. To the collar could be attached a basket or sack in which a person might be lowered to the ground.

Ladders—Fire Escapes.—Ladders fitted with wheels for ready transport from their stations to fires were provided by the Royal Society for the Protection of Life from Fire, shortly after its foundation in 1836. A commencement was made with six escapes, and in 1867 the Society had 85 stationed throughout the Metropolis of London. At this date they were transferred to the Metropolitan Board of Works for the use of the London Fire Brigade.

The Society also placed 47 escapes at various provincial towns in the United Kingdom.

The pattern adopted by the Society was known as the fly-ladder escape, and consisted of a main ladder 31 feet (9·5 m.) in length mounted upon a carriage with four wheels, two 6 feet (1·8 m.) and two 15 inches (0·4 m.) in diameter. Underneath the main ladder was a wire shoot reaching from the top to about 5 feet (1·5 m.) from the ground, where it was joined to an apron hammock. To the upper end of the main ladder was hinged the fly-ladder, 19 feet (5·8 m.) long, which was raised into position when required by hauling lines. A first-floor ladder and a supplemental length were carried, and when fully extended would reach 51 feet (15·5 m.). The weight complete was 13½ cwts. (66 kg.).

The pattern, being unsuitable, especially in narrow streets, caused the telescopic pattern to be introduced.

From time to time alterations and improvements have been made, and


Fig. 228.

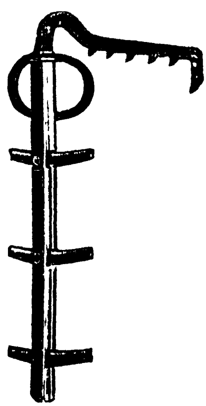


Fig. 229.

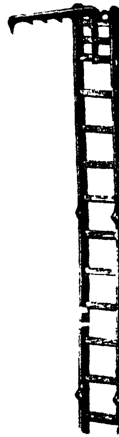


Fig. 230.

to this day many brigades in England use them, but few outside the United Kingdom.

In the author's opinion, all ladders exceeding 18 feet (5·5 m.) in length that are part of a fire brigade's equipment should be self-supporting—*i.e.*, attached to a carriage sufficiently heavy and rigid to allow the ladder to be used independently of any external support.

Hook Ladders.—The hook ladders of the present-day pattern are the result of many years' experience. First used in France and other Continental countries under the name of "Pompier" ladders, they were many years ago adopted by the American firemen, and became one of the principal parts of the equipment of their celebrated "Hook and Ladder Companies." The original pattern was as Fig. 228. They were altered in various ways until, in course of time, in the American form, they became a single pole, as Fig. 229. The use of the hook ladder did not become general in England until the latter part of the eighties, and was not adopted in the London Fire Brigade until after the International Fire Exhibition at Earl's Court, London, in 1903. The general style of ladder in use in England is as Fig. 230. For stowage these ladders can be hinged in the centre (see Figs. 231, 232, 233,

234, 235, and 236), but this is not recommended, as it adds considerably to the weight and makes the balance of the ladders more difficult. This question of weight and balance is very important to a fireman when scaling a building. The pattern now used by the London Fire Brigade is in one length, and has a folding hook that allows the ladder to be laid flat upon the other appliances, and yet the hook can be readily sprung out into position. As these hooks (Fig. 237) must be very strong, they are made of good steel of the smallest dimension possible for safety. The folding hook causes the balance of the ladder to be raised from the second round from the top, which in the case of a fixed hook is at the top round.

These ladders are made of the best selected well-seasoned English ash, the sides being $1\frac{5}{8}$ inches (0·04 m.) by $\frac{3}{4}$ of an inch (0·02 m.), and the treads 1 inch (0·03 m.) by $\frac{3}{4}$ inch (0·02 m.), fixed edgeways. The ladders are strengthened by steel pianoforte wire stretched tightly along the inside of each side, secured by a small screw top and bottom, and by a staple between each round.


Fig. 231.

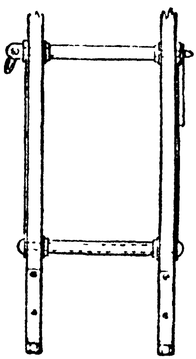


Fig. 232.


Fig. 233.

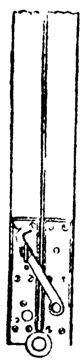


Fig. 234.

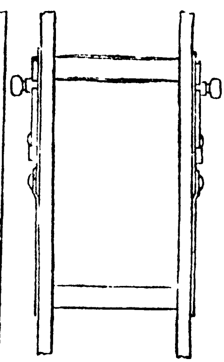


Fig. 235.


Fig. 236.

A turn is taken round the top round and the second from the bottom. They are further strengthened by three wrought-iron rods $\frac{1}{4}$ inch (0·0063 m.) in diameter fixed on the underside of the second, fifth, and eighth rounds; the rods pass through both sides, and are riveted on the outside with a copper washer.

The ladders are 13 feet 5 inches (4·09 m.) over all, and weigh about 28 lbs. (12·7 kg.).

Figs. 238, 239, 240, 241, and 242 show different pattern hooks.

For convenience in carriage a large type of Library ladder (Figs. 243, 244) is carried by some brigades.

Upon hand carts and trucks extension ladders are carried, the size and weight varying according to the length required. The principal detail is the more or less automatic action of the stops which retain the ladders in position when extended.

Scaling Ladders.—One of the most useful appliances that are provided for fireman are well-made scaling ladders.

There are two well-known patterns, the Italian and the so-called Military, each with six rounds or steps.

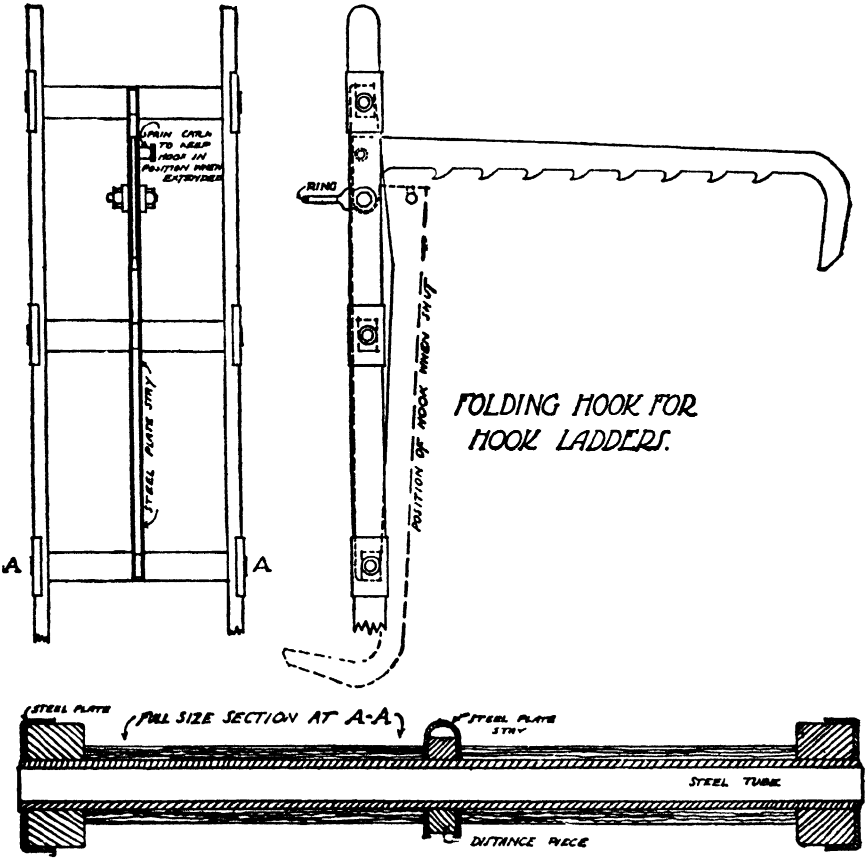


Fig. 237.

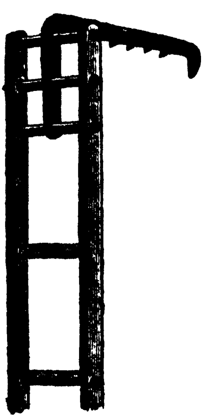


Fig. 238.

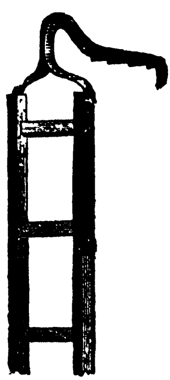


Fig. 239.

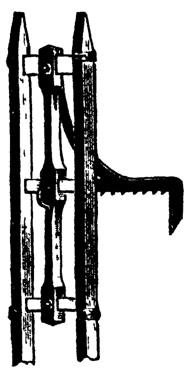


Fig. 240.

The Italian ladders have the steps rectangular, one in the lower end of the upper one passing through both sides sufficiently to take the upper end of another length, in the sides of which slots are cut to hold the projecting ends of the longer step ladder (Fig. 245).

The English or Military pattern has been carefully standardised for fire brigade work (the particulars of which are given in detail), the object being to make all Fire Brigade ladders interchangeable. With these ladders a resourceful fireman can get almost anywhere. The ladders will pass through small openings and can be erected in small areas, up burnt-out or unsafe

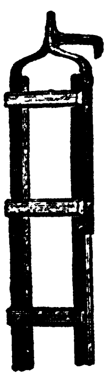


Fig. 241.

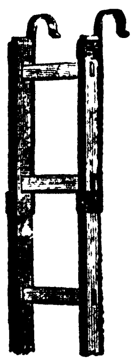


Fig. 242.


Fig. 243.

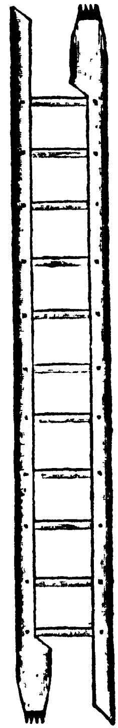


Fig. 244.

staircases—in fact, they can be taken to any place to which a man can conveniently get.

Specification for Scaling Ladder (Fig. 246).—Each ladder to consist of two sides, six rounds, twelve gunmetal castings, and four sockets.

The sides are to be of the best spruce, deal, or Oregon pine, perfectly dry and well-seasoned, and free from sap and dead or loose knots. Each side to be finished to measure 6 feet 6 inches (1·98 m.) long, 3¼ inches (0·83 m.) deep, and 1⅝ inches (0·41 m.) wide.

They are to be fitted together in taper as shown, the top being 3⅝ inches (0·09 m.) narrower than the bottom.

The ends are to be slightly chamfered on the outside at the foot, and on

the inside at the head, for about 3 inches (0·08 m.). Across the top of each side is to be cut a half-round groove $\frac{3}{4}$ inch (0·02 m.) deep, to take the lower round of the next length.

A wrought-iron rivet is to be inserted $1\frac{1}{2}$ inches (0·04 m.) from the top of each side, from front to back, securely fixed by being burred over washers carefully fixed and perfectly flush with the sides.

The rounds are to be formed out of well-seasoned oak free from cross-grain; cleft (not sawn), and then turned down to the proper sizes.

The diameter of the rounds to be $\frac{7}{8}$ inch (0·02 m.) where they enter the castings, and $1\frac{1}{8}$ inches (0·03 m.) in the centre.

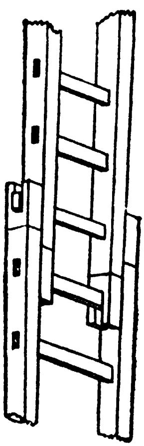


Fig. 245.

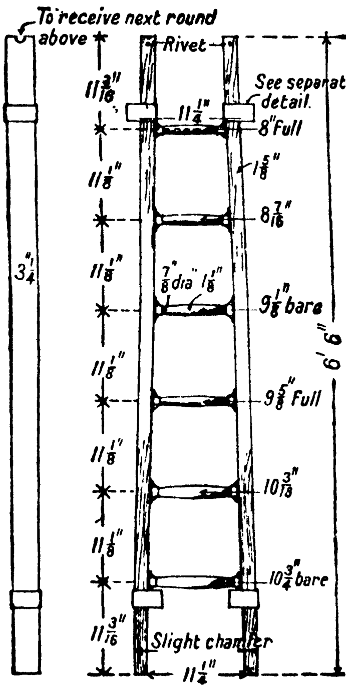


Fig. 246.—Scaling Ladder.

The rounds to have their ends carefully fitted into the gunmetal castings, and each end secured thereto by a small brass screw.

The sides are to be held together by having the first, third, and sixth rounds carefully bored out, and through the round a $\frac{1}{4}$-inch (0·006 m.) wrought-iron rod is to be passed. the ends of these rods to be screwed into washers $\frac{1}{8}$ inch (0·003 m.) thick, with $\frac{1}{4}$-inch (0·006 m.) round nuts to be of gunmetal tapered and grooved or slotted on the outside to take a forked screw-driver.

The length of the six rounds between the sides to be :—Lower, $10\frac{3}{4}$ inches (0·27 m.) bare; second, $10\frac{3}{16}$ inches (0·26 m.); third, $9\frac{5}{8}$ inches (0·24 m.) full; fourth, $9\frac{1}{8}$ inches (0·23 m.) bare; fifth, $8\frac{7}{16}$ inches (0·22 m.); top, 8 inches (0·2 m.) full.

The rounds to be fixed 11⅛ inches (0·28 m.) from centre to centre, and 11 3/16 inches (0·28 m.) from the top and bottom of the sides, making the full length of 78 inches (1·98 m.).

The 12 gunmetal castings (Fig. 247) weighing about 3 ozs. (0·09 kg.) each are to be fastened to the sides by means of two round-headed 1-inch (0·025 m.) brass screws.

When made up the ladders are to have at the foot a width of 11¼ inches (0·29 m.) inside the legs on sides, and also 11¼ inches (0·29 m.) outside at the level of the top round. These measurements are very important, in order that any one length may exactly fit at the head or foot of every other ladder.

The underside of the castings and the inside of the sockets to have a coat of thick red lead before being fixed in position.

Each length to be mounted with four sockets, which must be very carefully made so as to take any ladders made to gauge.

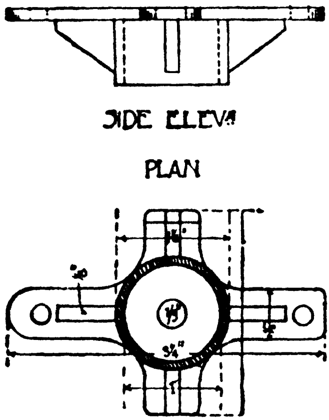


Fig. 247.—Rung Socket.

The four sockets are to be of good steel, 2 inches (0·05 m.) deep, about ⅛ inch (0·003 m.) thick, and exactly 3¼ inches (0·083 m.) square on the inside at the inner end, and 3¼ inches (0·083 m.) by 3 5/16 inches (0·084 m.) at the outer end, as shown in Fig. 248.

The weld in the socket to be in the middle of the part which, when screwed into position, touches the side of the ladder.

Four holes to be carefully drilled diagonally in the front and back of the sockets and the sockets fastened close to the top and bottom rounds by 1-inch (0·025 m.) screws. The holes in every case to be so arranged that the screw at the top of each socket is near the inner edge of the timber, and those at the bottom near the outer edge.

The inside of the projecting edges of the sockets top and bottom to have the edges bevelled to assist the entry of the other lengths.

The sides of the ladders to be properly sand-papered down and painted three coats of good oil paint, finished red, the irons black, and the rounds to have a coat of varnish.

In ladder-making it is important that after the timber has been carefully selected and cut, it should be laid upon a flat surface and kept in position under pressure to prevent warping. This procedure should be followed after each occasion that the wood is fashioned, and sufficient time allowed between each operation for the sap to exude and for any defects in the timber to show.

In cases where a number of Scaling Ladders are to be made or orders repeated, it is advisable to make a strong wooden platform or gauge marked with the position of the various parts.

Each ladder measures 6 feet 6 inches (1·98 m.), but when put together they overlap 11 inches (0·28 m.), therefore each ladder after the first only adds 5 feet 7 inches (1·70 m.) to the total length.

Each length will weigh about 22 lbs. (10 kg.).

Five lengths should be the maximum number used together unless they are properly stayed. When using a larger number than five the ladders are liable to sag back against the wall and fall over from the building. By careful staying with ropes or timber, front, back, and each side, they may be made secure for any length.

Line-Throwing Gun.—Attempts are made from time to time to sell these guns with their lines to brigades. In still air a steady shot can land the projectile somewhere near a mark, but in gusty weather the wind has such an effect upon the lines that any chance of hitting a 6-feet (1·8 m.)

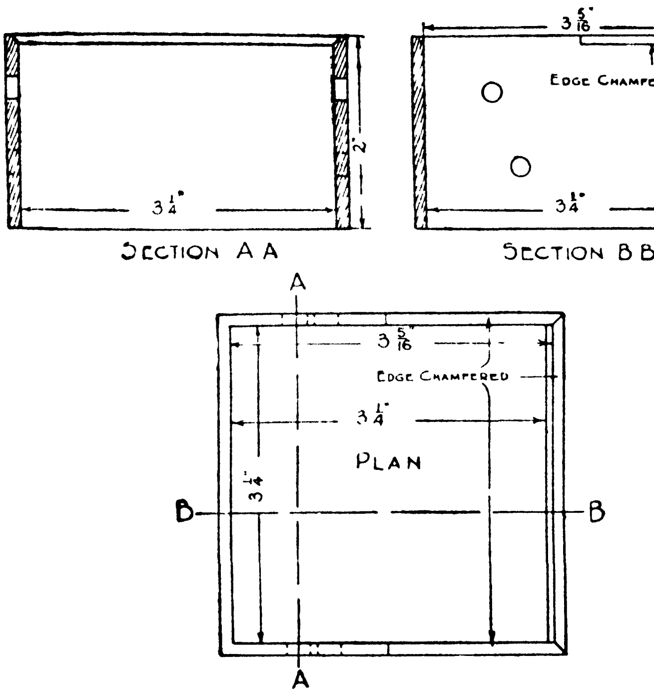


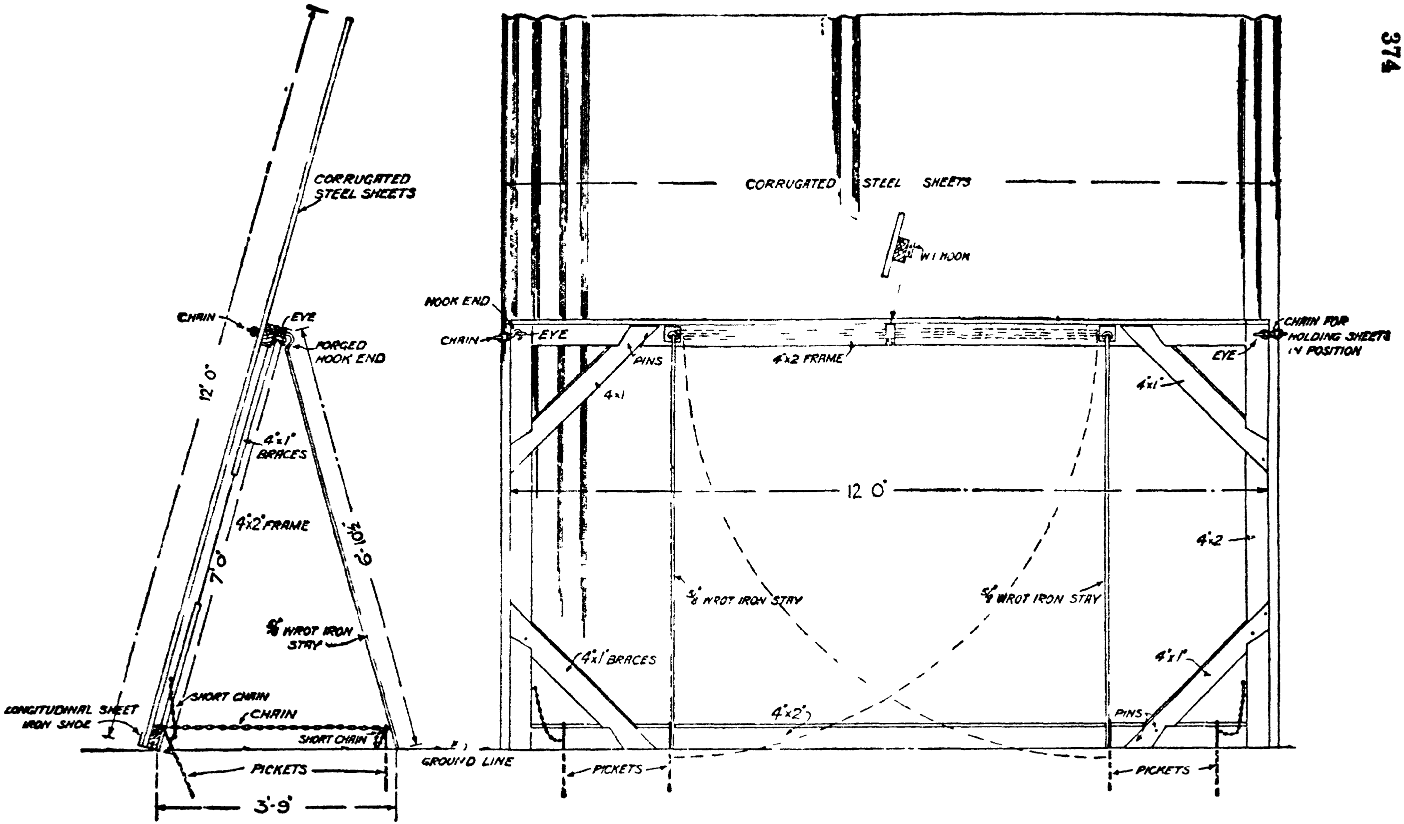
Fig. 248.—Steel Socket.

by 3-feet (0·9 m.) window that could not be flung into by hand is out of the question.

A small gun will, when held at an angle of 30°, carry a $\frac{3}{16}$-inch (0·005 m.) line 74 yards (68 m.). The larger guns give more accurate results, but take longer getting into position.

Mops and Sponges.—Mops and sponges attached to long poles were also freely used for fire extinction purposes long before Roman times, when buckets, hooks, and syringes were also employed.

A mop with the usual length of handle is a very handy article to attack an incipient fire, and can be used in connection with buckets with good effect upon the decorations or hangings from and on the surfaces of walls and ceilings of domestic buildings.



Section, Elevation.

Fig. 249.—Fire Screen.

Powder Fire Extinguishers.—See Dry Powder.

Respirators.—See Smoke Helmets.

Sand.—Sand may be used for smothering fires, but unless it is well-washed or silver sand, it has a tendency to cake when kept in receptacles.

Sandy soil or loam is usually to be found handy in most houses in flower pots or window boxes, and can be used to good effect upon surface fires or those caused by oil lamps. The moisture will reduce the temperature of the burning mass and the soil will absorb the spirit or oil.

The Saw for use at fires should have a stoutly made blade, and be not more than 4 inches (0·1 m.) wide at the handle end, and the teeth set out sufficiently to cut a clear space for the sawdust to fall out. Larger saws cannot be used with advantage in the small space a fireman has often to work. Weight of saw and leather case, 3¾ lbs. (1·7 kilo.).

Scaling Ladders.—See Ladders.

Screen Fire.—Fire screens are mostly provided for use in encampments and places where large quantities of combustible goods or buildings are situated.

Such encampments are usually for a temporary purpose, and would not justify the expense incurred in providing mains of an adequate size to supply water for fire extinguishing. If the encampments are for military purposes there is usually plenty of manual assistance at hand that can be utilised in placing screens in position.

Some screens are fitted upon wheels. Fig. 249 shows a pattern that can be stacked in a small space and is easily fixed.

Screw Wrench or Shifting Spanner should be carried, 9 inches (0·23 m.) in length, well made, with jaws to open 1¾ inches (0·04 m.); weight about 3 lbs. (1·36 kg.).

Many other implements are carried by some brigades as are found necessary. Country brigades have Hay Knives and Grappling Irons; others, insulated electric wire cutters and iron roof cutters.

Smoke Helmets and Respirators.—The history of attempts to produce apparatus providing a means of breathing smoke-laden air for any length of time affords the best idea of the difficulties that have to be overcome. Amongst these attempts some of the earliest were breathing-tubes, consisting of a muzzle fitting to the mouth with valves connected to which were long tubes, which remained in the open air, and down one of which the wearer breathed, whilst fresh air was sucked in through the other. These were exceedingly awkward to manage, especially when corners had to be turned, and the skin friction of the air passing through the tubes rendered respiration extremely hard.

An improvement of this idea was to have an air-bag with a short tube, which enabled a man to enter an atmosphere of smoke and remain in it for two or three minutes. A more complex apparatus was the smoke jacket, consisting of a blouse of cowhide fitted with a helmet over the head, the ordinary water hose being screwed into an inlet in the blouse, into which air instead of water was pumped by the engine, whilst in the same clumsy class of apparatus may be placed Aldini's fire-protecting suit, consisting of asbestos, covered by fine wire gauze and surmounted by a helmet.

In 1875, Professor Tyndall, in conjunction with Captain Shaw, devised and introduced the smoke-cap, which consisted of a hood of calf-skin, fitting

practically air-tight over the head and shoulders, and which carried goggles for the eyes, and in front of the mouth a valve for expired air, and a filter tube through which the air could be respired. The tube was closed with wire gauze at each end, and contained alternate layers of wool, wool moistened with glycerin, freshly burnt charcoal, and freshly burnt lime, the whole apparatus weighing about 4 lbs.

In such a smoke-filter the wool moistened with glycerin is especially active in retarding the passage of such particles of dust and vesicles of tar vapour as could pass the dry cotton-wool, whilst the charcoal exercised a certain amount of absorptive effect on the gaseous products of combustion, the lime taking up the carbon dioxide.

Indeed, the lessons of the late War have proved that respirators of any kind are at the most palliatives, and the only real remedy is to provide a supply of Oxygen.

From time to time new uses have been found for self-contained breathing apparatus. Many years ago, during work in connection with the Severn Tunnel, Mr. Fleuss produced a type of oxygen breathing apparatus for use in the water-logged railway ; this was the forerunner of the "Proto" pattern.

About the beginning of the last century, public attention was much attracted to the disastrous explosions that so frequently occurred in coal mines. After much study by chemists, Sir Humphrey Davy constructed his well-known safety lamp for use in coal mines and places in which an explosive mixture may be suspected. The great success attending the use of the Davy lamp caused scientists to turn their attention to providing apparatus that would allow men to enter and work in air charged with poisonous gases. Many types have been devised. Fleuss 1881, Pneumatophore 1896, Shamrock 1898, Mayer 1899, Giersberg 1900 and 1901, a combination of Shamrock and Giersberg 1903, 1904, and 1906, Draeger 1906, Aerolith (liquid air), Fleuss-Davis, Meco, Pneumatogen, Weg, etc. Improvements are being made at the colliery rescue stations throughout the world. Many of these stations have a very highly trained band of men who undertake the dangerous rescue work in connection with coal mines, entailing much longer periods of work than fall to the lot of firemen.

While the same kind of apparatus may be used, the supply of oxygen for a fireman may be considerably less than that carried by colliery brigades.

The requirements of the apparatus are that good air should be supplied to the man by providing sufficient oxygen to restore the exhaled air to its normal state. The apparatus must be compact and so arranged that the weight can be conveniently carried without unduly impeding the man's capability to do laborious work.

A supply of 2 litres of oxygen per minute is required for a man doing hard work, and in order to carry sufficient for two hours' work in a compact form the oxygen is compressed into steel cylinders at a pressure of 1,800 lbs. to the square inch (120 atms.). The expired air is passed through a filtering medium, usually caustic soda, carried in a bag or cylinder.

So much depends upon the details of construction that space will not permit of a full description of the many types upon the market.

Liquid Air.—Air can to-day be liquified on a scale which is limited only by the size of the machinery used. Expansion following high compression gives the necessary cooling effect, and eventually brings the air to its boiling

point ($-$ 184° C. to $-$ 196° C., at atmospheric pressure). Before the air is allowed to enter the expansion process, it is freed of its CO_2, oil and all humidity, the latter two processes taking place in the high pressure circuit.

Liquid air as used for underground rescue stations consists of 60 to 70 per cent. oxygen, and depends for its action on the fact that it expands to about 800 times its volume when returning to its gaseous state, furnishing some 12 cubic feet of oxygen from each pound of the liquid. The apparatus is usually charged with 10 lbs. of the liquid, and 1 lb. if the liquid is expected to give 20 minutes' supply of air.

Liquid air has been used with success in breathing apparatus, but owing to its instability (it evaporated at the rate of 10 per cent. per day) the cost was prohibitive.

As the most extensive duty firemen are likely to be called upon to do in gas-proof helmets, is searching a long length of sewer or an underground railway, the cylinders are not required to be so large as for mine work, but must be sufficient to well cover the time the men are likely to be occupied.

In practice it is found that only men medically fit, well trained, and in constant practice, can work successfully with these helmets. A set should be provided for each man allotted for this duty.

As many brigades cannot arrange for men to be especially allocated for smoke-helmet duty, they may be equipped with "Konig's" apparatus, which is a survival of the old air tubes mentioned above. It consists of a helmet, fitted with goggles, a valve for escaping air, and inlet, to which an air tube is attached; the neck of the helmet is made of soft leather, which straps round the man's neck. The air tube, which may be of any length, is attached to the helmet, the other end being fixed to a double-acting bellows worked by a man in the outer air, the bellows drives the fresh, cool air round the face of the wearer, and the air being under slight pressure prevents the entrance of most gases or smoke to the helmet, the air finally escaping through a valve in the top of the helmet.

Under most circumstances the pressure of the air in the helmet prevents the entrance of any gases or smoke to the helmet, but cases have occurred in which the action of the bellows has not been sufficiently constant to keep out small quantities of gas.

This form of smoke-helmet is popular with the men, as a small attachment near the bellows allows the tube to be used as a speaking tube, so that the man wearing the helmet can keep in communication with the man outside, and direct operations. Thus the feeling of isolation is done away with.

A wet handkerchief or cloth placed over the mouth and nostrils will to some extent act as a filter and allow a man to remain in smoke for a short time and enable him to make a dash and do small jobs, such as to turn off the cock of a gas meter, or open doors or windows.

Tools, Small.—Beyond the gear supplied by the makers with all new engines, a number of appliances or tools are necessary to complete the requirements of a properly equipped fire brigade. They are:—

A large axe, one of those known as a felling axe, will answer the purpose, with a head 10 inches (0·25 m.) long, fitted with an ash handle 3 feet (0·91 m.) long, weight 7 lbs. (3·18 kilo.). The principal use of these axes by firemen is to break open doors. A special pattern axe has been made with the solid

end of the head thickened out upon the handle side, so as to present a flat face to the woodwork without bringing the knuckles of the fireman close in to the face of the door. The upper side of the head having a projection, and being finished like a claw hammer.

Turncock's Tools.—See Hydrant Keys.

CHAPTER XIII.

ROPES AND KNOTS.

All varieties of cordage having a *circumference* of an inch (0·03 m.) or more are known by the general name of rope. Twisted cordages of smaller dimensions are called cords, twines, and lines, and when the dimensions are still smaller the article becomes thread or double yarn. All these varieties of cordage are composed of at least two, and in most cases of very many separate yarns, which are textile fabrics drawn out and twisted into a uniform compact line.

From thread and fine twine upwards the whole art of manufacture is simply that of twisting together fibres and yarns, but the comparative heaviness and coarseness of the materials operated on in rope-making render necessary the adoption of strong machinery.

The size of a rope is denoted by its circumference in inches. Its length is measured in fathoms.

Rope is made from the fibres of *hemp, manilla, coir, and cotton.*

Hemp fibre is obtained from the hemp plant, and is found in three main varieties, the strength of which differs considerably.

Italian hemp has a white silky fibre, and is the strongest of the three varieties. It is used in the manufacture of all white hemp rope, except spunyarn, and for tarred bolt rope. *Riga* hemp has a green tinge and is coarse grained. It is always tarred, and is used for tarred hawser-laid ropes up to 6 inches (0·15 m.), and for lashings. Inferior qualities are made into spunyarn. *Petrograd* hemp is also greenish and coarse grained, and is the weakest of the three varieties. It is always tarred, and is used for tarred hawser-laid ropes over 6 inches (0·15 m.). It is also made into spunyarn.

Manilla fibre is obtained from the outer fibres of the leafstalk of a species of plantain. It is more elastic than hemp fibre, and rope made from it is less affected by wet and less likely to kink; it is, however, rather too elastic for lashings.

Coir fibre is obtained from the outer husk of the cocoanut. It is always used in an untarred condition. It is very light and elastic, and will float until it becomes saturated with water. When constantly wet it does not rot as hemp would. *Cotton rope* is used upon yachts and for driving ropes of machinery.

When several fibres of the material are twisted together they form a yarn. Several of those yarns twisted together form a strand, and three or more strands twisted together form a rope.

The system on which the strands forming the rope are twisted together is called the " lay " ; the variations in system are as follows :—

Bolt-rope.
Hawser-laid, 3-strand, twisted up from left to right.
Hawser-laid, 4-strand or shroud-laid, with a central core in addition to the four strands.

These terms really indicate the tightness in which the strands are laid up, and the three varieties can be measured in the finished rope by the angle between the direction of each strand and the direction of the centre line of the rope. These angles are as follows :—Bolt-rope, 36½° ; hawser-laid, 3-strand, 42° ; and hawser-laid, 4-strand, 45½°.

In addition to the foregoing, three 3-strand ropes are sometimes laid up together, twisted from right to left, the rope thus formed being termed *cable-laid.*

Increasing the angle of the lay makes the rope weaker, but more durable against wear. These large ropes are now almost entirely replaced by wire hawsers, which are much stronger and more handy.

Tarring rope weakens it, but preserves it from rotting. If white rope receives proper care and stowage it should not deteriorate, and it is some 30 to 50 per cent. stronger than tarred, and about 20 per cent. lighter.

Spunyarn is made from 3 to 9 yarns.

To identify a piece of rope the following points must be specified :— Material, lay, whether tarred or white, and size.

The varieties of rope, with their Breaking Loads, are given in the following Tables :—

SAMPLE MIMIMUM BREAKING LOADS (from Government Specification).

Nature of rope.		Breaking load. Cwts. per (circ. in inches)².
Hemp, bolt, 3-strand, tarred . . .	5-inch.	7·60
,, ,, ,, . . .	2 ,,	7·50
Hemp, hawser, 3-strand, tarred . .	4 ,,	6·25
,, ,, ,, . .	3 ,,	6·66
,, ,, ,, . .	2 ,,	6·75
,, ,, ,, . .	1 ,,	8·00
,, ,, white . .	9 ,,	8·15
,, ,, ,, . .	4 ,,	9·06
,, ,, ,, . .	1 ,,	12·00
Manilla, ,, ,, . .	5 ,,	7·36
,, ,, ,, . .	2½ ,,	7·44
,, ,, ,, . .	1 ,,	9·00
,, ,, ,, . .	5 ,,	8·10
,, ,, ,, . .	2½ ,,	9·60
,, ,, ,, . .	1 ,,	10·50
Coir, ,, ,, . .	9 ,,	1·58
,, ,, ,, . .	5 ,,	1·60
,, ,, ,, . .	2½ ,,	1·54

EXPERIMENTAL BREAKING LOADS OF COMMERCIAL ROPE.

Nature of rope.	Breaking loads. Cwts. per (circ. in inches)².
Hemp, tarred	(average) 4·94
,,	(maximum) 8·31
,,	(minimum) 3·19
Hemp, white	(average) 6·76
,,	(maximum) 8·52
,,	(minimum) 5·54
Manilla,	(average) 7·64
,,	(maximum) 10·56
,,	(minimum) 4·25
Cotton,	(average) 4·64
,,	(maximum) 5·71
,,	(minimum) 3·68

EXPERIMENTAL BREAKING STRESSES OF COMMERCIAL STEEL WIRE ROPES.

Nature of rope.	Breaking stress. Tons per (circ. in inches)².
Wire core, ungalvanised	(average) 3·08*
,, ,,	(minimum) 2·55
,, galvanised	(average) 3·62*
Hemp main core, ungalvanised	(average) 3·20
,, ,, ,,	(maximum) 4·51
,, ,, ,,	(minimum) 2·43
,, ,, galvanised	(average) 2·70
,, ,, ,,	(minimum) 1·92
,, ,, and strand cores, ungalvanised	(average) 2·76
,, ,, ,, ,, galvanised	(average) 2·25
,, ,, ,, ,, ,,	(maximum) 3·52
,, ,, ,, ,, ,,	(minimum) 1·77

* These figures are based on but few experiments; in general they would be higher.

EXPERIMENTAL VALUES OF THE BREAKING STRESSES OF IRON AND STEEL WIRE.

Nature of wire.	Breaking stress. Tons per square inch.
Iron wire,	(average) 32
,,	(maximum) 44
,,	(minimum) 26
Steel wire,	(average) 97
,,	(maximum) 142
,,	(minimum) 46

The *weight* of various patterns of rope differs very considerably, but as a rough rule the weights may be taken as follows :—

Hemp and manilla, tarred, . . . $\frac{C^2}{4}$ lbs. per fathom.

Hemp and manilla, white, . . . $\frac{C^2}{5}$ lbs. per fathom.

Coir, ... $\frac{C^2}{10}$ lbs. per fathom.

where C is the circumference in inches.

The *strength* of rope is an important point, but its tensile strength alone need be considered. The strength of rope of the same nature varies within a large range, but the average for any particular kind depends upon—

1. *Material.*—The following are in decreasing order of strength :— Italian hemp, manilla, Riga hemp, Petrograd hemp and coir.
2. *Lay.*—The following is the decreasing order of strength :—Bolt-rope, hawser 3-strand, hawser 4-strand.
3. Whether tarred or white. The former is considered about 30 per cent. weaker than the latter.
4. *Size.*—The larger sizes of rope are not so strong in proportion as the smaller ones.

In common with other materials, the strength of rope ought to be expressed by the intensity of the ultimate stress. As the sizes of rope, however, are given in terms of the circumference, it is found more convenient to express the strength in terms of a load, multiplied by the square of the circumference.

More than *one-third* of the ultimate load should never be put on a rope, and a larger factor of safety should generally be employed, expecially if using worn ropes and with a live load. The safe working load of all rope, with the exception of coir, has consequently been laid down as follows :—

$$C^2 \text{ cwts.},$$

where C is the circumference in inches. This may be increased for good rope, in good condition, up to a maximum of—

$$2\,C^2 \text{ cwts.}$$

The safe working load on coir rope can be taken as—

$$\tfrac{1}{4}\,C^2 \text{ cwts.}$$

It may be noticed that the expression C^2 cwts. gives an intensity of stress about 1,400 lbs. per square inch (0·984 km. on mm.^{2}).

Rope stretches considerably when loaded. In certain cases it might be useful to know approximately the amount of stretching that will take place under a given load.

When a piece of rope has been in use some little time a fair proportion of the stretching becomes permanent, and the elongation for any given load will, therefore, be less. Different pieces of rope, even of the same nature,

vary in the amount they stretch, but the following rough rules will give the average values for new rope; due allowance would have to be made for rope that has been in use :—

$$\left.\begin{array}{ll}\text{All hemp and manilla rope,} \quad . \quad . & \frac{1}{2}\sqrt{\frac{S}{C}} \\[2ex] \text{Coir and cotton rope,} \quad . \quad . \quad . & \sqrt{\frac{S}{C}}\end{array}\right\}\ \text{Percentage of elongation on original length.}$$

where S is the total stress in lbs., and C the circumference of the rope in inches.

The *strength* of ropes when slung over hooks or fastened by knots is decreased about 30 per cent. This is due to the fact that at the bend the intensity of stress in the fibres is not uniform, and some of the outer fibres are, in consequence, liable to fail. If it is required to work the rope up to its full working load, thimbles or their equivalent must be used, and the mode of attachment so chosen that no sudden bend takes place in the rope. If thimbles are not available, waste or old sacking can be inserted between the hook and the bight into which it is hooked.

Rope should be kept as dry as possible, and when not in actual use should be coiled clear of the ground. If unavoidably exposed to weather it should be protected by tarpaulins or other coverings.

The following technical terms employed with rope are in common use and their meaning should be understood :—

1. *The running end* is the name given to the free end of a rope.

2. *The standing part* is the rest of the rope.

3. *Belaying a rope* is making it fast to another object, and a rope made fast is said to be bent.

4. *Paying out* or easing a rope is slackening it out.

5. *A bight* is a loop formed on the rope so that the two parts lie alongside one another.

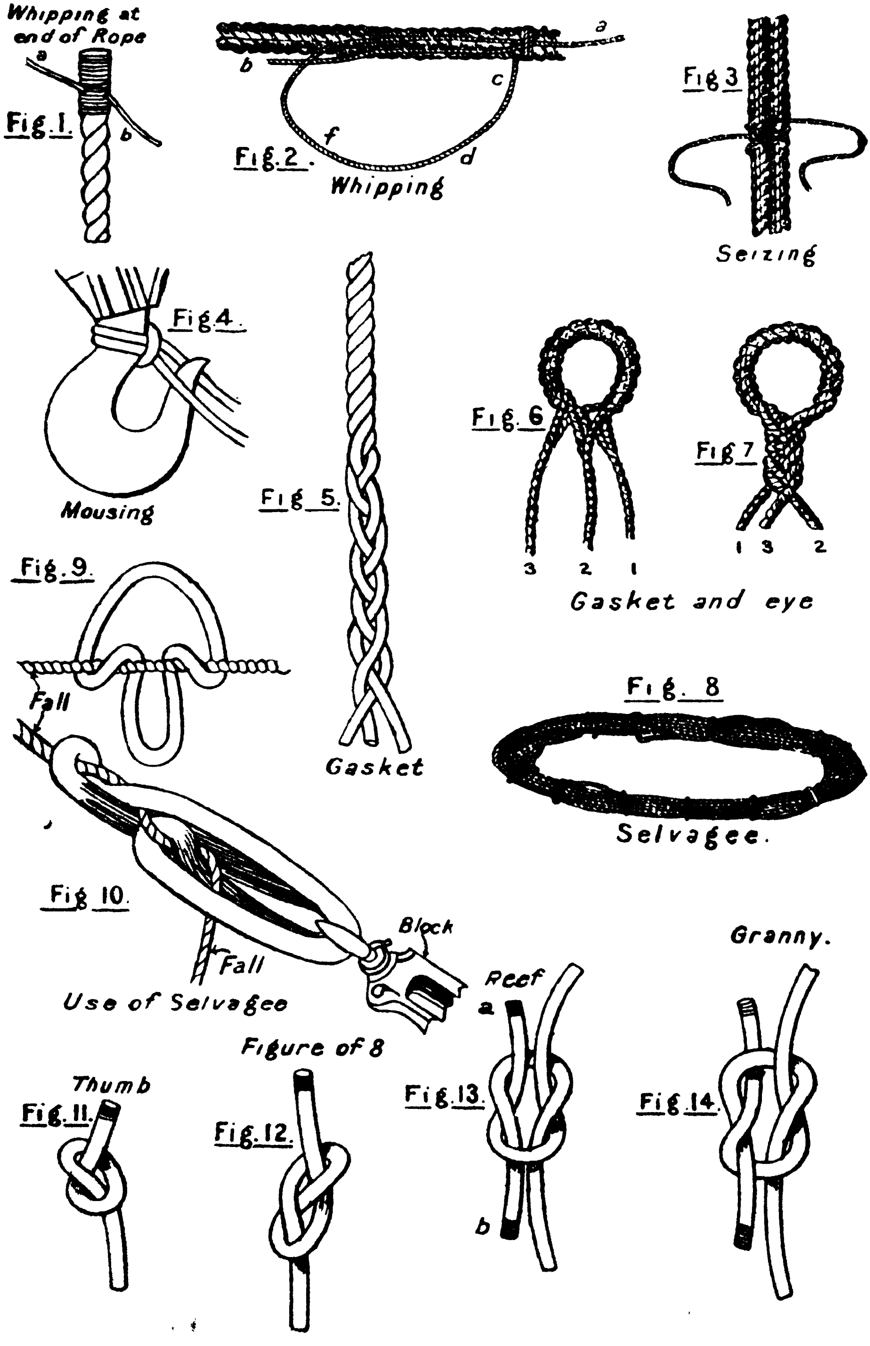
6. *A half-hitch* is a loop made so that one part crosses the other.

7. *Whipping a rope* is tying a piece of twine round the end to prevent it from untwisting and fraying. To whip a rope lay the end of the whipping along the rope, with its point towards the end, and take some turns round it and the rope towards the point. When half the required number of turns have been made, lay the end back from the point of the rope and lay the other end of the twine alongside the first, then twist the standing part of the loop so formed round its running part and the rope, until the required number of turns have been taken, after which pull the two ends, one towards the end of the rope and the other in the opposite direction, till they are tight, and cut them off close to the whipping. (Plate I., Fig. 1.)

Another way is to take a piece of twine about 2 (0·61 m.) or 3 feet (0·91 m.) long, according to the size of the rope, and place it with one end (*a*) lying to the right, the other (*b*) along the rope to the left. Wind the part (*c*) (*d*) (*f*) tightly round the end of the rope and the two ends of the whipping twine (*a*) and (*b*) the requisite number of times. Then by pulling the ends of the twine (*a*) and (*b*) the whipping is tautened up and completed. (Plate I., Fig. 2.)

PLATE I.

KNOTS.



8. *Pointing a rope* is tapering the end so that it can more easily enter a hole or block.

9. *Parcelling a rope* is putting canvas well daubed with tar round it, and binding it with spunyarn. This is used on portions of rope exposed to chafe.

10. *Frapping* is the drawing together of the several returns of a rope or twine lashing by passing the rope or twine round all the returns.

11. *Seizing a rope* is connecting two parts together with a lashing of spunyarn, etc. To seize a rope, take a piece of spunyarn and double it. Place the bight round both ropes to be seized and pass the ends of the yarn through the bight. Haul taut by pulling on the ends in opposite directions, and make fast with a reef knot after as many turns have been taken as are necessary. (Plate I., Fig. 3.)

Another way is to take the centre of the yarn and tie a clove hitch with it at the required point on one of the ropes; then take each part round and round the two ropes in opposite directions, leaving one end long enough to take two frapping turns between the ropes; the ends are then connected by a reef knot. (Plate II., Fig. 4.)

All bends and many other knots can often be made more secure by seizing the running end to the standing part.

12. *Mousing a hook* is securing a lashing of spunyarn to the mouth of the hook to prevent its clearing or disengaging itself from anything it may be hooked to. To mouse a hook, take a piece of spunyarn, double it, pass the bight round the back of the hook and the ends through the bight. Two or three turns are then taken with the ends in opposite directions round the back and point of the hook, frapped together and secured by a reef knot. (Plate I., Fig. 4.)

Another way is to make the centre of a piece of spunyarn fast with a clove hitch to the back of the hook. Both ends are passed round the back and point of the hook several times, frapped and finished with a reef knot. (Plate IV., Fig. 7.)

13. *A gasket* is a flat-plaited part of a rope, used for stopping. (See stopper hitch.) It is made from one or two pieces of rope, according to the size required. Seize the rope where it is intended to end the gasket, unstrand it up to the seizing, separate the yarns, slightly untwist them and whip their ends; then divide them into from three to nine portions, called foxes, and plait the foxes together. If the gasket is to be thinned off towards the end, the foxes must be thinned at intervals near the end of the plait. (Plate I., Fig. 5.)

Another way of forming a gasket is to unstrand a rope and lay the three strands side by side and serve them over with yarn.

A gasket can be made with an eye to it as follows:—Take a piece of rope, double the length required, form a bight in the centre of the rope and seize it at the end of the bight. Unstrand the rope up to the seizing, and call the strands 1, 2, 3, and 4, 5, 6, respectively. Interweave these strands as follows—Pass 1 over 4 and under 5, and unite it to 6; 2 and 5 work together, and 3 works with 4, which crosses under 1. The whole of the yarns having been opened out up to the seizing and united in the order above, the three strands thus made are plaited together. To taper it off a few yarns are gradually taken off each strand. (Plate I., Figs. 6 and 7.)

The strength of a gasket when used as a stopper is found to be about 40 per cent. less than that of the rope it was made from.

14. *A selvagee* is formed of rope yarns coiled into a circular form and marled down. To make it, plant two pickets at a distance apart equal to the intended length of the selvagee, wind yarn rope round them until the skein is thick enough, and then marl it all round with the same yarn, half-hitched round it at intervals of an inch, and finish off with two half-hitches. The pickets must not draw in at the top or else the yarns will not all be of the same length. (Plate I., Fig. 8.)

It can be applied to a rope or a spar, as shown in Plate I., Figs. 9 and 10; but the best way is to lay the middle of the selvagee on the cable, turn the right hand end round under the cable and take hold of it in the left hand; then pass the other end under the cable to the right, but riding over the first part, and take it with the right hand. Pass the end, now in the right hand, to the left over the cable and the other end to the right over-riding it, and so on till near the end of the selvagee, when the hook of the block is hooked into both loops. A selvagee holds well on wire ropes. It provides a quick way of applying a block to a spar, and is more quickly applied than a gasket for stoppering.

Knots and Splicing.—It is important that knots should be tied tightly, correctly and without hesitation. A knowledge of knots cannot be acquired from books; it is essential that practice in tying them should be continued until they are thoroughly learnt.

Knots may be divided into several groups as follows :—

1. Knots to make a stop on a rope.

Thumb Knot.—To make this knot, pass the end of the rope over the standing part and then up through the loop thus formed. (Plate I., Fig. 11.) This knot is also used to prevent a knot from unstranding.

Figure-of-eight knot.—To make it, pass the end of the rope under, round above and down below the standing part, then upwards through the bight thus formed. (Plate I., Fig. 12.) This knot is more secure than a thumb knot.

2. Knots for joining or bending ropes together.

Reef knot.—This knot is made as follows :—Holding one rope in each hand, ends to the front, lay the end of the right-hand rope over the left, and take it towards the left once completely round that held in the left hand, so as to bring the point again to the front. Turn it back in the direction of and alongside its standing part over the original left-hand end. Bring the latter up round the first end, down through the loop and haul taut. (Plate I., Fig. 13.) The standing and running parts of each rope must pass through the loop of the other part in the same direction—that is, from above downwards or *vice versâ*. If they pass in the opposite direction the knot is what is termed a granny, and when tightened up cannot be undone as easily as a reef knot can. (Plate I., Fig. 14.)

A reef knot can be upset and the ends pulled out by taking one end of the rope and its standing part and pulling them in opposite directions. A reef knot is used for small dry ropes of the same size, with dry rope it is as strong as the rope; with wet rope it slips before the rope breaks, while a double sheet bend is found to hold.

Draw knot.—This knot is the same as a reef knot, except that a bight

instead of an end is drawn through at A. (Plate II., Fig. 1.) It can be cast off from a distance by pulling on the end B.

Single Sheet bend.—This knot is made as follows:—Take a bight or double at the end of one rope, holding it in the left hand, and pass the end of the other rope held in the right hand up through this bight, down on one side, under and up over the bight, and under its own standing part. (Plate II., Fig. 2.) This is used for ropes of unequal size, or where the stress on the rope is not continuous. It is a more secure knot than the reef knot, but is more difficult to undo.

In the *double sheet bend* the running end is passed twice round the bight and under its own standing part each time, without overriding. (Plate II., Fig. 3.) It is used where greater security is required, especially with wet ropes, as it is found to hold till the rope breaks.

Hawser bend.—This bend is made as follows:—Make a bight at the end of one of the hawsers, take a half-hitch with the running end round the standing part, lash them together just beyond the hitch, and seize the running end to the standing part. Pass the end of the other hawser through the loop so formed, take a half-hitch round its standing part, and seize as before. (Plate II., Fig. 4.) This bend is used for very large cables. For greater security two half-hitches can be made in each hawser. By taking a complete turn with one rope round the loop of the other before making the half-hitches, the strength of the bend is largely increased, more bearing surface being obtained, and the tendency to part at the loop to a great extent done away with.

3. Knots to attach ropes to other ropes or spars.

Half-hitch.—This is made by passing the running end of a rope round the standing part and bringing it up through the bight; it may be seized to the standing part. (Plate II., Fig. 5.)

Two half-hitches are made as follows:—With the end of the rope in the right hand and the standing part in the left, pass the ending of the rope round the standing part, and up through the bight, thus forming one half-hitch. Two of these alongside one another complete the knot. (Plate II., Fig. 6.) The end may be lashed down or seized to the standing part by a piece of spunyarn, which adds to its security, and prevents the end from slipping. This is specially used for belaying or making fast the running end of a rope on to its own standing part.

Round turn.—This and two half-hitches, is the same as the last, with the exception that a complete turn is taken round the spar or other object to which the rope is to be fastened, and the half-hitch is taken afterwards round the standing part. (Plate II., Fig. 7.) Should the running end be inconveniently long, a bight of it should be used to form the half-hitches.

Rolling hitch.—This is made as follows:—With the end of a rope take two turns over the spar, then make two half-hitches round the standing part, the end being seized if the rope is stiff. (Plate II., Fig. 8.) This hitch is always easy to cast off.

Fisherman's bend.—This bend is made as follows:—A complete turn is taken round the ring or other object to which the rope is to be fastened, and the end is passed over the standing part between the turn and the ring, over its own part, thus forming one half-hitch, and a second half-hitch is taken round the standing part alone. (Plate II., Fig. 9.) This is used to

fasten cables to the rings or anchors, and in all water work where a give-and-take motion has to be met.

Clove hitch.—This hitch can be made in two ways, dependent on whether it is possible to slip the knot over the end of the spar or not. In the first case, grasp the rope with the left hand, back down, and right hand, back up. Reverse each hand so as to form two loops. (Plate II., Fig. 10.) Lay the two loops together so that the one held in the right hand is inside the other, and slip the double loop so formed over the end of the spar. (Plate II., Fig. 11.) When the rope has to be secured to a spar over the end of which the knot cannot be slipped, pass the end over and round the spar and bring it up to the right of the standing part and again over and round the spar, to the left of the first turn, and bring the end up between the spar, the last turn, and the standing part. (Plate II., Fig. 12.) This is specially used for securing the running end of a rope to a spar as, for instance, in beginning a lashing; it is also used for securing guys to the heads of spars. When used in lashing spars the end should be twisted round the standing part—and, for guys, seized to the standing part. A rope end secured by a clove hitch breaks near the clove hitch with less weight than if eye-spliced, or bent and seized. As this knot is one of the most useful and most frequently required, considerable practice should be devoted to making it in various positions. It will be noticed that a clove hitch is the same as two half-hitches pulled together.

Mangus hitch.—This hitch is made by passing the end of a rope twice round a spar, then bringing it up before the standing part, passing it again round the spar on the opposite side to the first turn, and up through the bight which is made, the end part being jammed by it. (Plate II., Fig. 14.) This is used for making fast to round spars when much friction is necessary to prevent slipping.

Draw hitch.—To make this hitch, pass a bight of the running end round the holdfast. Pass a bight of the standing part through the first bight, and haul taut on the running end. Pass a bight of the running end through the second bight and haul taut on the standing part. (Plate III., Figs. 1, 2 and 3.) This knot will stand a give-and-take motion, and can be instantly released by a jerk on the running end. It is used to secure a head rope, boat's painter, etc., to a post, ring, or rope, so that it can be instantly released.

Timber hitch.—This is made as follows:—Pass the end of the rope over and round the spar and round its own standing part close to the spar. Then twist it at an easy angle two or three times back round itself, and haul the fell taut, thus jamming the twisted end against the spar. (Plate III., Fig. 4.) It is used for securing foot-ropes, etc., and can be easily undone when the strain is taken off it.

Killick hitch.—This hitch is begun by making a timber hitch, and completed by a half-hitch. (Plate III., Fig. 5.) It is used for hauling and lifting spars, the half-hitch being placed near the end of the spar to be moved.

Stopper hitch.—This hitch is made as follows:—Take one turn with the stopper round the cable towards the side on which it is wished to relieve the tension, and then a second turn overriding the first. Pass the end of the stopper up between its standing part and the second turn, then over the standing part of the stopper down under the cable and round three or four times in direction of the tension and the turns in the opposite direction

KNOTS.

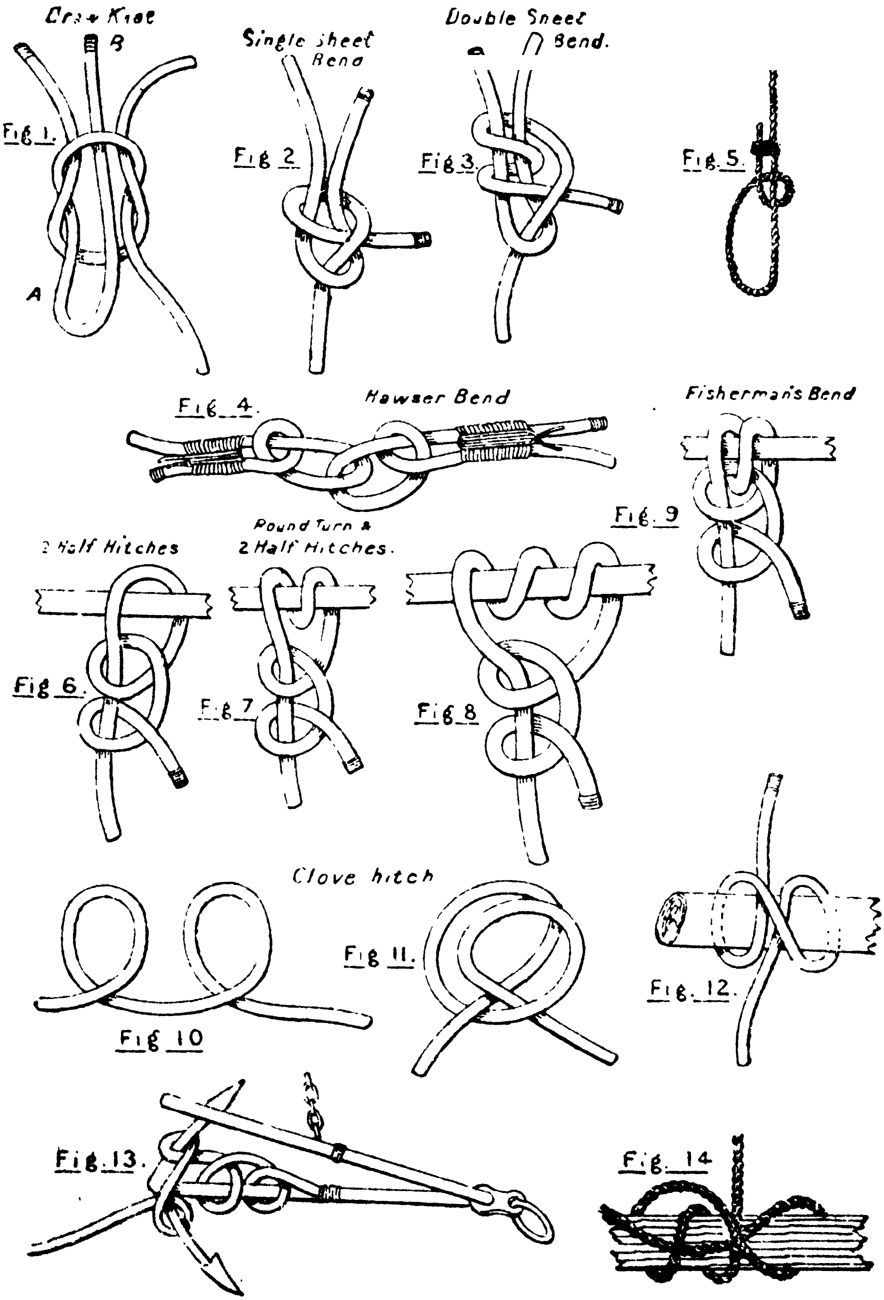


Fig 1.
B
A
Single Sheet Bend
Fig 2
Double Sheet Bend.
Fig 3.
Fig 5.
Fig 4.
Hawser Bend
Fisherman's Bend
Fig 9
2 Half Hitches
Round Turn & 2 Half Hitches.
Fig 6.
Fig 7
Fig 8
Clove hitch
Fig 10
Fig 11.
Fig 12.
Fig 13.
Fig 14

to the original ones; its end is then seized to the cable. (Plate III., Figs. 6 and 7.) It is used for making a hitch that will not slip with one rope or chain on a second rope or spar. A gasket is useful for a stopper.

4. Knots to make a loop on a rope.

Bowline.—A bowline is used for forming a loop that will not slip at the end of a rope. To make it, lay the forefinger of the right hand along and above the running end, hold the standing part away from the body with the left hand, back down; lay the running end over and at right angles to the standing part just in front of the left hand; turn the right hand over and outwards, bring the forefinger up through the small loop which is formed on the standing part; then holding this small loop with the left hand, pass the running end under the standing part and up again, and then down through the small loop and haul taut. (Plate III., Figs. 8 and 9.)

To make a bowline on a bight, double the rope, and laying the bight—held in the right hand—over the two ends held in the left hand, start making a bowline as before. Then open out the doubled end, pass it over the whole of the knot and to the front again, but now under the two ends, taking care that the knot does not turn over; then haul taut. (Plate III., Fig. 10.) This is used for making a loop that will not slip in the middle of a rope. See also Chair Knot, Figs. 254 and 255.

Running bowline.—A running bowline forms a loop which can easily be slipped along a spar and tightened at any point. To make it, pass the running end round the spar and take hold of it with both hands (the end in the right hand) as far apart as appears desirable, and so that the standing part passes over the running end between the hands. Then, with the end in the right hand, tie a bowline on the running part near the left hand. The knot is then run through the loop. (Plate III., Fig. 11.)

Lever hitch.—This is made as follows:—Make a loop with the rope, standing part uppermost, loop away from the body, bring it round half way across and over the standing part, then pass a lever or bar over the side of the loop under the standing part and haul taut. (Plate III., Figs. 12 and 13.) It may be used with a lever to withdraw pickets, etc., or to secure the rounds of a rope ladder, or in connection with drag-ropes. A pair of drag-ropes at a convenient distance apart, with parallel bars secured by these knots, enable several men to pull abreast.

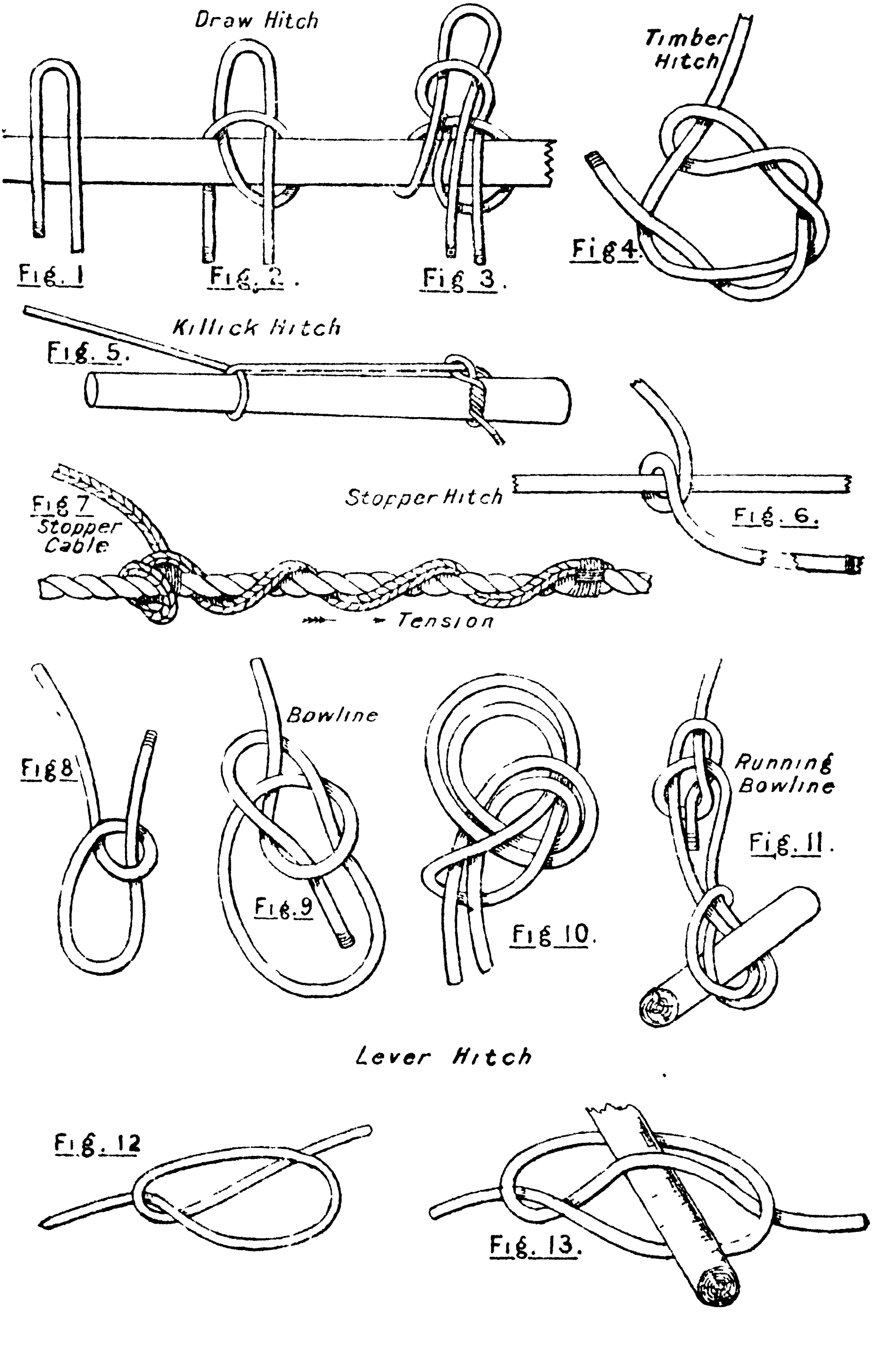
Man's harness hitch.—This hitch is begun like the lever hitch, but is completed by taking the side of the loop which is a continuation of the standing part, bringing it under the standing part and up between the standing part and the other side of the loop and hauling taut. (Plate IV., Fig. 1.) This forms a loop to pass over a man's shoulder to assist him in dragging on a rope.

Running knot.—The knot is formed by making a thumb knot with the running end round the standing part. (Plate IV., Fig. 2.) This makes a loop that will draw taut round an object.

Slip knot.—To make this knot, take a bight on the end of a rope and grasp it in the left hand, bight towards the left; turn the running end back on the bight, take three turns with it round the three parts of the rope away from the bight, and pass the running end up through the small loop on the right and haul taut. (Plate IV., Fig. 5.) This knot can be slipped over a spar and tightened up at will.

PLATE III.

KNOTS.



5. Knots for use with blocks.

Blackwall hitch.—This hitch is made as follows:—Make a half-hitch well up on the shank of the hook and haul taut, when the running end will be jammed against the curved part of the hook. (Plate IV., Fig. 3.) This is used for fastening the end of a fall to the hook of a block; it only holds while the stress is on.

Double Blackwall hitch is made by placing the rope against the top of the hook of the block at the front. The returns are then crossed at the back of the hook, and again inside the hook. (Plate IV., Fig. 4.) This is much more secure than the single Blackwall.

Single sheet bend.—This bend is a good mode of fastening a fall of a tackle to the ring or becket of a block, as this allows the blocks to come chock or close together. (Plate IV., Fig. 3.)

Cat's paw.—A cat's paw at the end of a rope is made as follows:—Take two equal bights, one in each hand, and roll them over the standing part till surrounded by three turns of the standing part, then hook the block into both loops. (Plate IV., Figs. 6 and 7.) A cat's paw in the middle of a rope is formed as follows:—Lay the rope across the palms of the hands turned upwards, turn the hands inwards and continue doing so until the rope is twisted on itself two or three times by either hand, then bring the two loops thus formed together, and hook the blocks through them both. (Plate IV., Fig. 8.)

To sling a cask horizontally, form a bight at the end of the rope with a bowline, take a side of the bight in each hand (backs upwards) and give them a turn backs downwards, forming two loops. Pass the loops over the ends of the cask and haul taut. (Plate V., Fig. 1.)

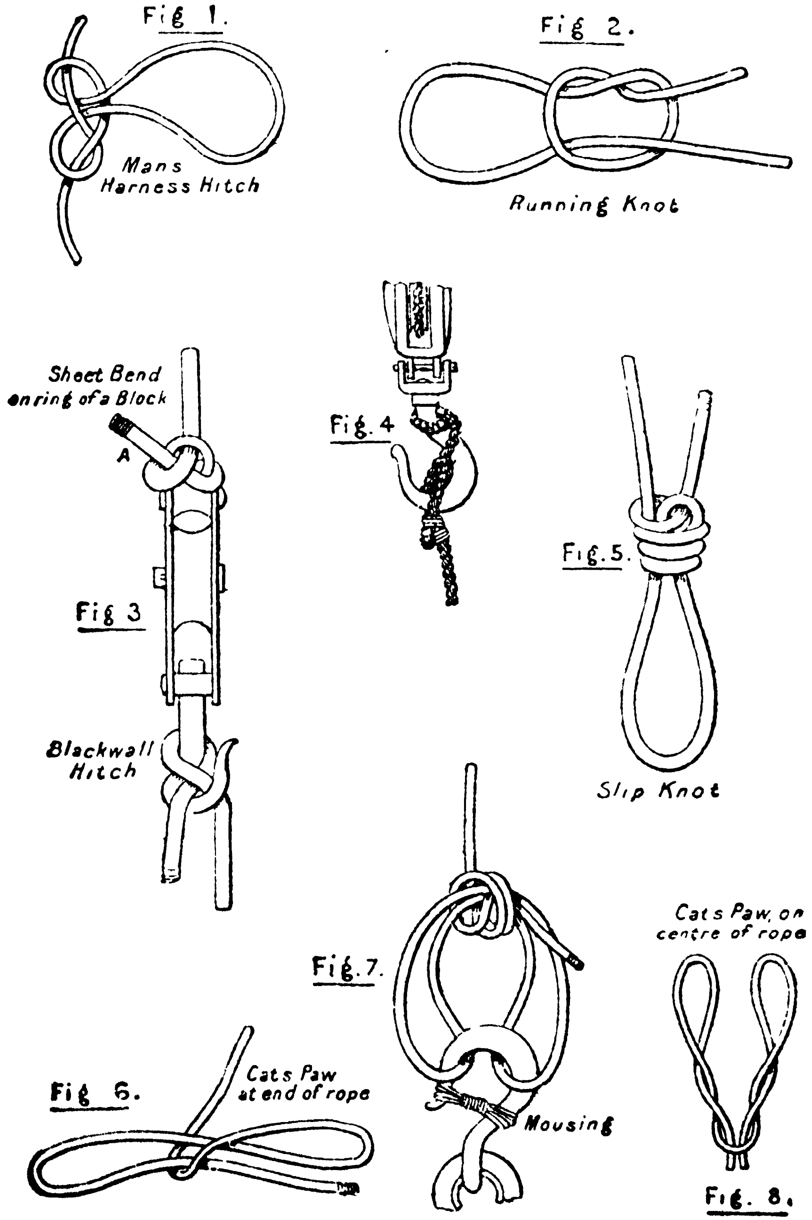
To sling a cask vertically, lay the rope on the ground and place the cask on it about twice the length of the cask from the running end, then with both parts of the rope tie the first half of a reef knot on top of the cask, open out and pass the loop thus formed over the head of the cask half-way down to the bung; adjust the sling and make fast the running end to the standing part of the rope with a bowline. (Plate V., Fig. 2.)

A cable is belayed to a cleat by taking a round turn round the cleat, and as many figure-of-eight turns as may be necessary. This may be finished off with a half hitch on one arm of the cleat; but this should never be done if the cable may have to be cast off in a hurry.

Rope is sometimes united by splicing instead of by knots. To make an eye splice, unstrand a length of the end of the rope about two and a half times its circumference, and then bend the end down to the standing part, forming an eye of the required size, laying the middle strand on the top of the rope and forcing it from right to left under one of the strands of the standing part, having previously opened them with a marlin spike. The left-hand strand is then forced from right to left over one strand, and under the next on the left. Having turned the rope round to the left, so as to bring the right-hand strand on the top of all, force it from right to left under the strand of the rope immediately on the right of the one the first or middle strand was passed under. Each strand of the end is now passed in succession between the strands of the standing part, no two contiguous strands being passed under the same strand, and each strand of the end being taken alternately over and under the strands of the standing part. The strands

PLATE IV.

KNOTS.



are opened by means of a marlin spike, at the same time twisting the rope in a direction opposite to its lay, thus causing the hole to keep open when the marlin spike is withdrawn. The strands on being put through should be drawn taut. They should be worked in twice, then halved and worked in once, and then halved again and worked in to complete the splice. When the splice is complete, these ends are cut off and the splice beaten down with a wooden mallet. (Plate V., Figs. 3, 4 and 5.) An eye splice is nearly as strong a fastening as a bend with seizings, and stronger than a clove hitch.

To make a short splice, the ends of the two ropes to be spliced are unlaid and the strands are married—that is, the strands of one rope placed between the strands of the opposite rope and drawn taut. The strands of one rope may then be seized to the other rope, while the splicing of the other strands is proceeded with by passing each strand from right to left over and under alternate strands in the opposite rope, in a similar way to that described for the eye splice. The strands of the other rope are then treated in the same way and the splice completed. (Plate V., Figs. 6 and 7.) Such splices have been found to be as strong as the rope.

A long splice is used when it is required to join up two ropes in such a way that they can still be rove through the same size blocks as before. This is effected by splicing each pair of strands at an interval of 2 (0·61 m.) or 3 feet (0·91 m.) from the other strands. Begin by unstranding the end of each rope for a length of 2 (0·61 m.) or 3 feet (0·91 m.), according to the size of the rope (not less than seven times the circumference of the rope), and marry the two ends described for the short splice, bringing the unstranded portions well against each other. Select a pair of strands (one from each rope) which come opposite to each other, and twist them loosely together so as to get them out of the way temporarily. Then begin unstranding one strand of one of the ropes, replacing it carefully by the corresponding strand of the other rope to 3 (0·076 m.) or 4 inches (0·101 m.) from its end. Twist these two ends together to get them out of the way also, and then unlay the remaining strand of the second rope and replace it by the remaining one of the first rope. Now untwist each of these last strands and divide them into two equal portions, one portion from each strand being cut off and the other two being tied in a thumb knot, so as to fill up the vacant space in the lay of the strands. These ends are then twice taken over one strand and below the next on each side of the knot and then cut off, and the whole dressed down with the mallet or marlin spike. The other strands are then spliced in the same manner and the splice thus completed. (Plate V., Fig. 8.) It is found from experiment that a long splice is from 5 to 40 per cent. weaker than the rope.

In making splices which have not to run through a block, the ends of the strands should not be cut off close to the rope, but half an inch should be left projecting.

Fig. 250 will explain the cut and horse-shoe splices.

To within the lifetime of many men all ropes were made of vegetable fibre, but since the introduction of iron, and particularly of mild steel, rope made of this latter material is rapidly superceding all others, even for running gear.

In the case of steel wire rope the quality of the steel employed may vary considerably, and the strength of the resulting rope is also different.

SLINGING. SPLICING.

Fig 1.

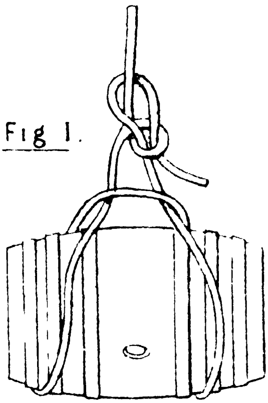
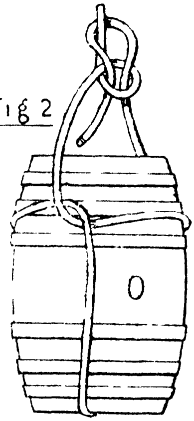


Fig 2



Slinging a Cask Vertically

Fig 3.

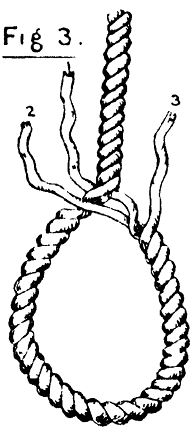


Fig 4

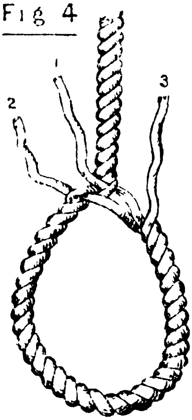
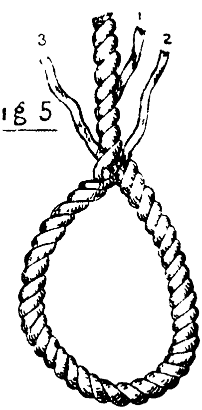
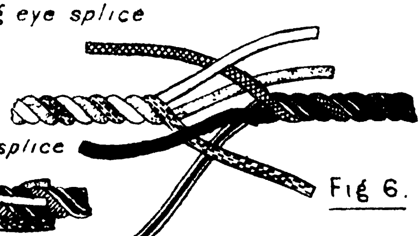


Fig 5



Back View

Forming eye splice



Short splice

Fig 6.

Fig.7.

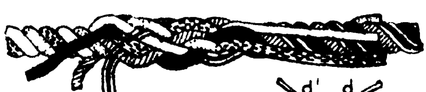
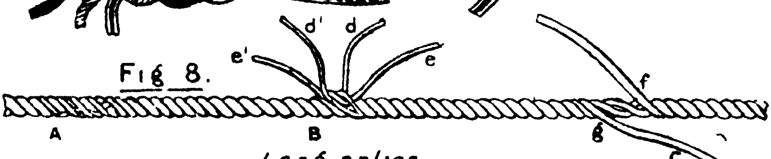


Fig 8.



Long splice

The wire for rope should be galvanised and may be made up in several different ways, as follows :—

1. Iron or steel wire alone is used in making the rope. The core of each strand consists of an iron or steel wire, round which the other wires are

Fig. 250.—Splices.

1. Cut splice. 2. Short splice. 3. Long splice. 4. Horse-shoe splice.

twisted. If the rope is composed of several strands, one would be placed at the centre of the rope, and the others twisted round it.

2. Strands composed entirely of wires as above are laid up round a hemp core.

3. Each strand contains a hemp core, and if the rope is composed of

several strands one would be placed at the centre of the rope and the others twisted round it. This type of rope is not very common.

4. Each strand contains a hemp core, and the rope is composed of several such strands laid up round a hemp core. This is the most usual type of rope.

A "laid" rope consists of a heart composed of a strand of either hemp or wire, round which are twisted 6 strands, each composed of 6 wires round a heart.

A "formed" rope comprises 6 strands laid round a heart as above, but each strand contains a larger number of component wires—that is, for example, round the first 6 wires a further outside layer of 12 would be laid, thus making 18 wires in all, independent of the core.

A cable "laid" rope consists of 6 laid ropes closed together to form one cable. Though this is more supple than the ordinary form of rope and lighter, it is decidedly weaker, and is not generally considered a good way of making up wire ropes.

Other arrangements of the wires are met with, but the above are the most common. As a rule the wires in any one rope are of the same size, though in ropes of some manufactures wires of two or more gauges are employed.

The flexibility of wire ropes is principally dependent upon the multiplication of their component wires, and the manner in which they are laid. It is comparatively easy to make a rope containing only a few wires, but it requires considerable skill and experience as the number increases to arrange the wires and their lays, so that each component wire shall bear its due and proportionate amount of working stress. Hemp cores produce a more flexible rope, but naturally a weaker one for the same diameter. It is usual to steep the hemp in hot linseed or other vegetable oil. This weakens the hemp, but the presence of any acid is highly detrimental to the life of a wire rope.

It is usual to take the weight of wire rope as equal to C^2 lbs. per fathom, C being the circumference in inches. This is approximately correct; but the real weight varies with the relative proportion of hemp core in the rope, this expression giving too high a value when there are hemp cores in the strands as well as in the rope itself.

The strength of wire ropes depends upon a great number of factors. As in the case of vegetable fibre ropes, the breaking and the working stresses are expressed in terms of a load per circumference squared.

The material of which the ropes are made is the principal factor. The breaking stress of special "agricultural" steel wire ropes, may vary from 3 C^2 tons to 4 C^2 tons; that of ordinary steel wire ropes, from 2 C^2 tons to 3 C^2 tons; and that of iron wire rope and very mild steel wire rope from C^2 tons to 2 C^2 tons. A very common mistake is to assume that any steel wire rope that is about to be used is made of the special "agricultural" steel wire, and its strength calculated accordingly. As a matter of fact, such wire ropes would only be found in cases where lightness is so essential that the considerable increase of cost would have to be disregarded.

Another important factor is the material of which the various cores, both main and strand, are made. Hemp cores add practically nothing towards the strength of the rope, and the chief consideration is consequently the ratio that the total area of the wires bears to the area of the rope.

The variation of this ratio is shown by the following average results for galvanised wire ropes of three different types :—

	Ratio of wire area to total.	Comparative strength.
Wire cores, ...	·55	1·8
Hemp main cores, ...	·46	1·5
Hemp main and strand cores, . . .	·30	1

With ropes containing a hemp core the larger sizes are stronger in proportion, as the proportional area of the hemp core is less.

The lay or arrangement of the wires also effects the strength of the rope. Generally speaking, a rope made up of a considerable number of wires is stronger for the same circumference than a rope made up of a smaller number of larger wires. On the other hand, ropes made of wires of several different sizes are generally weaker.

Galvanised wire ropes are on the average about 5 to 10 per cent. weaker than ungalvanised ropes *of the same circumference*, due to the fact that the wire is increased in diameter by the process without being increased in strength.

Splicing wire rope.—There is a hemp heart in each strand, and a heart the size of the strands through the centre of all. In making a long splice. care must be taken to unlay the strands without taking the turn out. It is well to unlay them in pairs. The unlaying of each pair can be continued when they are married. At least 3 feet (0·9 m.) will be required for each strand in splicing a fair-sized rope; this will mean 18 feet (5·5 m.) in all This rope is first put together as if splicing an ordinary three-stranded rope Take one pair of strands, unlay them singly, and lay them up clear of each other for splicing, till these six pairs of ends are at suitable distances apart. Thrust a spike right through the heart of the rope at one end of the splice, leaving three strands to either side of the spike. Pull out the bight of the hemp heart with another spike, cut it a few inches to either side, and work the two ends of the wire rope into its place. This is easily done by moving the first spike about in its place. Cut the end of the strand you are working on, and butt it against the end of the heart in the centre. Proceed in like manner with all the strands; the parts will then jam in tightly together, and look very neat. Fig. 251 shows the splice in various stages. In the case of a hawser, the ends of the strands may be tucked once to ensure safety, though this precaution is scarcely necessary.

In making an *Eye Splice*, there are various ways of tucking the ends, but only one will be noticed here. When the size of the eye is determined on, fix a light seizing on the wire, about 2 feet (0·6 m.) from the end (Fig. 252, 1), unlay the ends to this seizing, and bend the wire to the shape of eye required. Hang this bight up with a piece of line, so that the splicing part comes about level with the chest. Place the main part of wire to the left; divide the unlaid strands so that three are on the left, and three on the right of the main rope; proceed to tuck the first end on left under two strands of the main wire, and so on with the others as shown in Fig. 252, 2, placing each of these, however, under one strand only, Fig. 252, 3.

Fig 251 —Stages of Splicing Wire Ropes

1. Unlaid in pairs 2. Unlaid in singles. 3. First tuck 4. Final tuck.

Take care to enter all in one way, that they may come out in their proper lay. Haul the strands fairly tight, and hammer them into their places, leaving a small space in the neck of the splice. Then tuck the strands twice under one strand only, taking care not to make the tucks too short, or a lumpy splice will be the result; now halve the strands, and tuck once.

Remember that the neatness of a splice depends a good deal upon the manipulating and humouring of the strands.

When the ends are cut off, a judicious application of the spike and hammer will finish the splice, which should then be parcelled with oiled canvas and

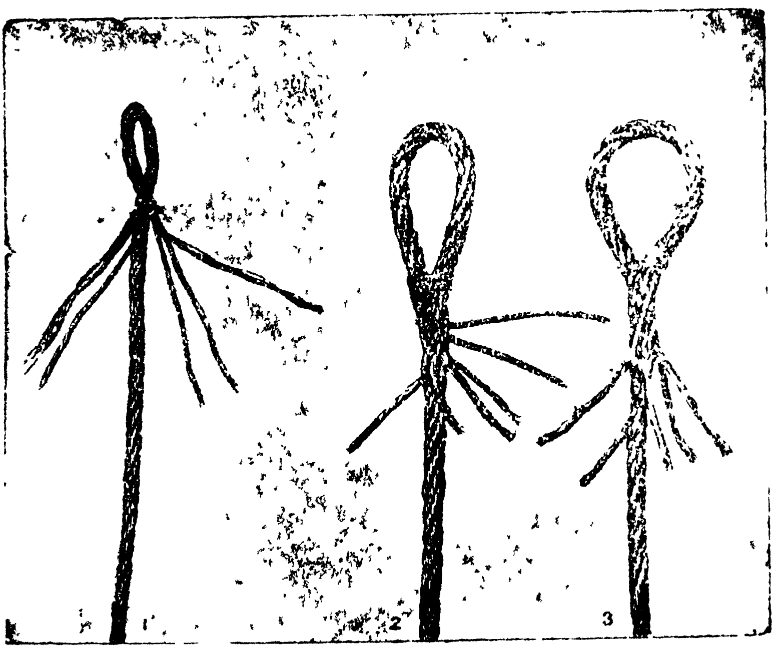


Fig. 252.—Eye Splice.

neatly served over. Amber line should be used for this purpose for large ropes.

*Notes on wire ropes.**—The diameter of barrels and sheaves given in the rope tables is the extreme minimum for slow speeds. Better working results, in all cases, will be obtained by increasing the diameter of sheaves or barrels.

Running ropes should always be ungalvanised.

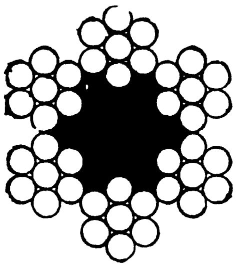
Never work a rope with a riding part, or allow it to overlap.

A kink cannot be taken out of a rope by strain, only by throwing the "turn" out.

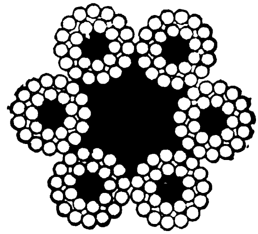
Never reeve a rope direct from the coil, put it on a wheel or reel and run it off.

* From "Elementary Seamanship," by Captain Sir D. Wilson-Barker. Charles Griffin & Co., Ltd., Nautical Series.

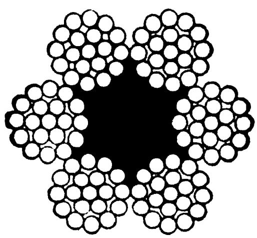
Always keep your ropes well oiled or greased; any lubricant will do as long as it does not contain acid or alkali.



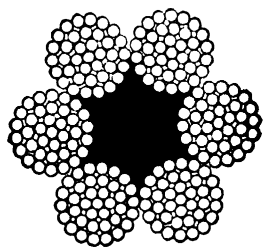
Laid Rope.—This rope is made 6 strands of 7 wires; it is the class of rope usually used for hauling ropes where the size of barrel and sheave will permit. It is also the make of rope usually used for standing rigging, and is such as is required by Lloyds' regulations.



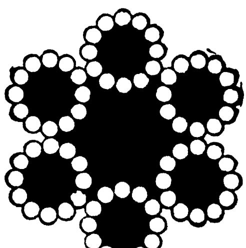
Extra Flexible Steel Wire Rope.—Made of 6 strands each of 24 wires.



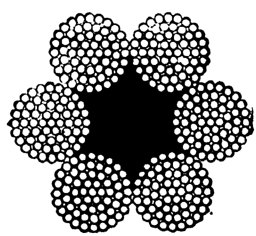
Formed Rope.—This is made 6 strands of 19 wires. In larger sizes this make of rope is used for standing rigging on vessels. In smaller sizes it is sometimes used for running rigging, and it is the usual make of rope for trawl warps.



Special Extra Flexible Steel Wire Rope.—Made of 6 strands each of 37 wires.



Flexible Steel Wire Rope. — Made 6 strands each of 12 wires, with hemp heart and hemp centre in each strand. This is the usual make of Flexible Steel Wire Rope, 4½ in. circ. and smaller; used for hawsers, running lifts, hoists, &c.



Special Extra Flexible Steel Wire Rope.—Rope made of 6 strands each of 61 wires. This is the make of rope usually adopted for large ropes—say over 10 in. circ.—and which are largely used for Slip way and salvage purposes.

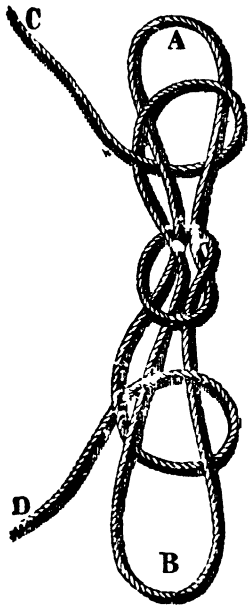
Fig. 253.—(Bullivants').

The sign of an overloaded rope is excessive stretching.
Stock ropes must be kept free from moisture, and in a dry place.

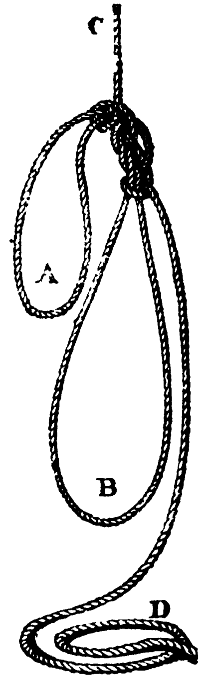
BULLIVANTS' GALVANISED FLEXIBLE STEEL WIRE HAWSERS AND CABLES COMPARED WITH HEMP AND CHAIN.

Flexible Steel Wire Hawsers and Cables.				Chain Cable.				Short Link Chain.			Tarred Hemp Rope.		
Size Circumference.	Weight per Fathom.	Guaranteed Breaking Strain.	Diameter of Barrel or Sheaves round which it may be at a slow speed worked	Size.	Weight per Fathom.	Proof Strain.	Breaking Strain.	Size.	Proof Strain.	Breaking Strain.	Size.	Weight per Fathom.	Breaking Strain.
Inches.	Lbs.	Tons.	Inches	Inches.	Lbs.	Tons.	Tons	Inches.	Tons	Tons	Inches.	Lbs.	Tons.
12	115	320	72										
11	97	270	66										
10	80	220	60										
9	65	180	54										
8	53	150	48	2 5/16	280	96¼	134¾	...	...	...	25	146	125
7½	47	130	45	2 3/16	256	86⅝	120¼	...	...	...	24	134	115
7	41	116	42	2 1/16	231	76½	107 1/10	...	...	...	23	123	106
6½	37	102	39	1 15/16	204	67¾	94½	...	...	...	21	106	89
6	33	88	36	1¾	166	55⅝	77½	...	...	...	19	84	72
5½	28	74	33	1⅝	143	47½	66½	...	...	...	17	67	60
5	23½	64	30	1 7/16	112	37⅝	55¾	...	...	...	15	56	50
4½	15	39	27	1⅜	68	22¾	34⅜	...	...	...	13	39	34
4	12	33	24	1	54	18	27	1⅛	15	34	12	33	29
3½	9	20	21	15/16	48	15 8/10	23 7/10	1	12	26	11	28	24½
3¼	8	22	19½	7/8	35	11⅝	17 8/10	15/16	10½	23	10	23	20
3	7	18	18	13/16	30	10⅝	15⅜	7/8	8	17	9	19	16½
2¾	5½	15	16½	¾	25	8½	12¼	¾	6¾	15	8½	16	14
2½	4½	12	15	...	...	...		11/16	5½	12	7½	13	11½
2¼	3½	9	13½	11/16	21	7	9½	⅝	4⅜	10	6½	11¼	10
2	2¼	7	12					½	3	6	5¾	9	8
1¾	2	5½	10½	9/16	17	5½	7¼	...	...	...	5	6½	6
1½	1½	4	9	...	...	...	...	...	...	...	4	4	4
1¼	1	2½	7½	½	14	4½	6	...	...	...	3½	3¼	2¾
1	¾	1½	6	...	...	...	...	...	...	...	2¼	2	1¾

The well-known chair-knot (Figs. 254, 255) is formed of two unequal loops about 30 inches (0·76 m.) and 42 inches (1·07 m.) long for an ordinary sized person. A quick way of forming the knot is to make a double overhand knot, then draw the bights through, one over 2 feet (0·6 m.) and the other over 3 feet (0·9 m.), the total length being made equal to the span of a man's arms when opened at full length; after the length is adjusted pass a half-hitch over each bight and down close to the knot. The two ends



Knot in course of formation.



Knot hardened up and ready for use.

Fig. 254.

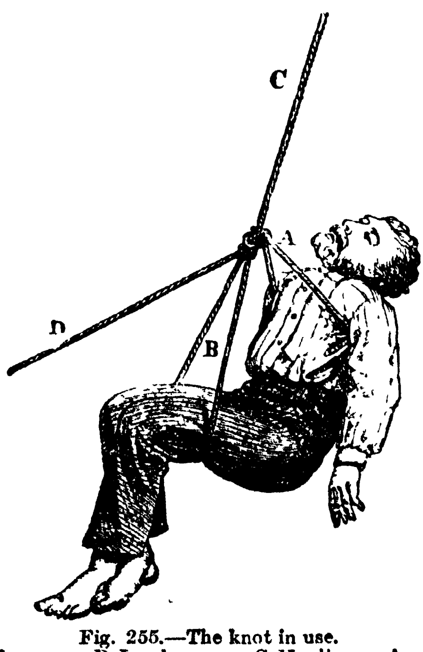


Fig. 255.—The knot in use.

A Arm hoop. B Leg hoop. C Hauling part. D Guy.

can then be used as required. The short bight should be at the hauling end and the long bight next the guy.

It is important that the person should be properly placed in this knot by having the small end under the arms and the longer end at the back of the knees. When properly fixed in this knot and slung, the person cannot get out, however they may struggle; at the same time, no undue pressure is caused upon the body (see Figs. 254 and 255).

Another way is to place the end of a rope under the foot, bring it up to the height of the chin, again round the foot twice (making five lines), tie a knot in the centre and you have four loops and two loose ends that can be used as a chair-knot.

The *Safety First* movement has brought out many devices for ensuring protection of men when working in dangerous positions or situations where noxious gases may be suspected. Most of these contrivances are in the form of belts, so arranged that the person to be rescued is kept head upwards. (See Fig. 256.)

Fig. 256.

CHAPTER XIV.

PHYSIQUE--DISCIPLINE—CLOTHING—HEALTH—PAY—FIRST-AID—MEDALS AND REWARDS.

Physique, discipline, training, clothing, and recreation are the all-important matters in every well-organised Fire Brigade so far as the *personnel* is concerned.

The physique of a brigade must of necessity conform to the corporeal standard of the people from whom it is recruited, but should be kept at as high a degree as possible.

The old standard of the London Fire Brigade was 37 inches (0·94 m.) round the chest, and at least 5 feet 6 inches (1·68 m.) in height. A test of strength was also required—viz., to pull up an escape from the horizontal to a vertical position; this required a pull of 240 lbs. (109 kg.) until half-way up, when it reduced to 200 lbs. (91 kg.), falling to nothing. This was reduced in February, 1911, to 140 lbs. (64 kg.), as the supply of recruits from sailing ships could not be obtained.

Most brigades dispense with any trial of strength, and are satisfied with a general appearance of strength and stoutness, health, and intelligence, the men being in other respects eligible. All firemen, paid or voluntary, should be medically examined by a surgeon, who thoroughly understands the arduous duties a fireman may be called upon to perform.

Discipline is a difficult force to explain, but it may be divided into discipline of love and discipline of fear. Without good discipline, a fire brigade is next to useless as an effective force, and as this depends entirely upon the officers, it is necessary that the Chief Officer should be a man who has full control of himself, is courteous to all, and who on no account swears at his men. Nothing is so demoralising in an organised force, and so subversive of true discipline as want of steadiness upon the part of those in command.

An officer should thoroughly understand his duties, or he cannot instruct and lead others. In order to be efficient it is advisable for a candidate for a Chief Officership to undergo a course of training in a subordinate position with a brigade of recognised standing and efficiency.

A good fire brigade officer should have well-balanced strictness when upon duty, and a kindly nature off duty, if he wishes to maintain in his brigade that perfect efficiency and *esprit de corps* that should characterise all well-organised brigades.

One of the duties of a Chief Officer demanding good judgment is the appointment of men to fill the positions of officers under him.

Punctuality should be observed upon all occasions, as nothing is more discouraging than for men who, perhaps at some inconvenience, have attended at the proper time, to be kept standing about waiting for the drill or lecture to commence.

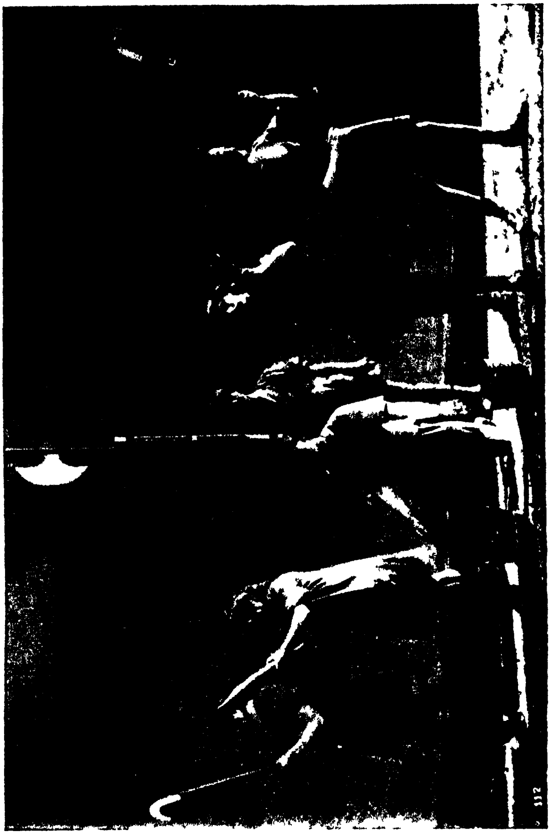


Fig. 257—Roman Matriculæ.

Fig 258—Firemen of 1696.

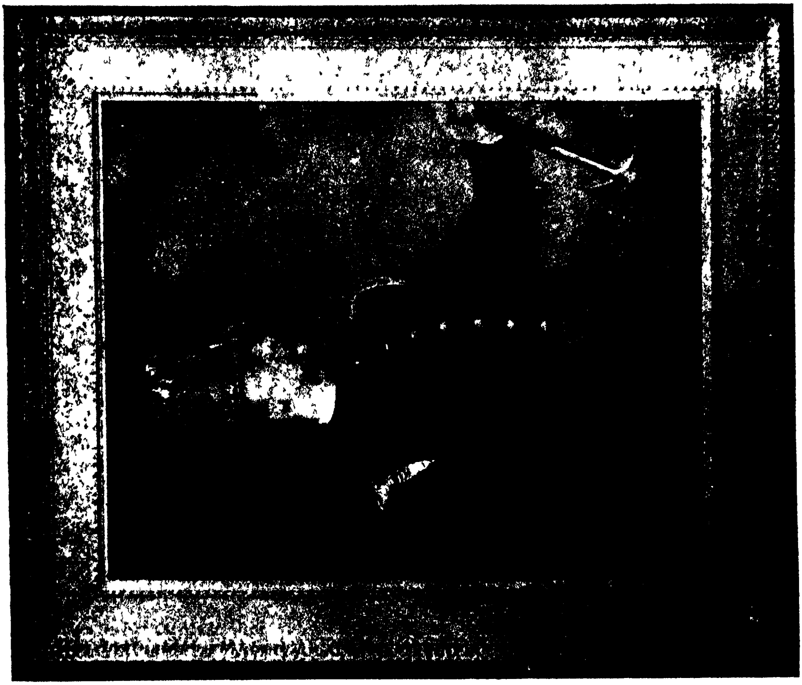


Fig. 260.—Portrait of Sir Eyre Massey Shaw, K.C.B.
(*By Henry Weigall, A.R.A.*)

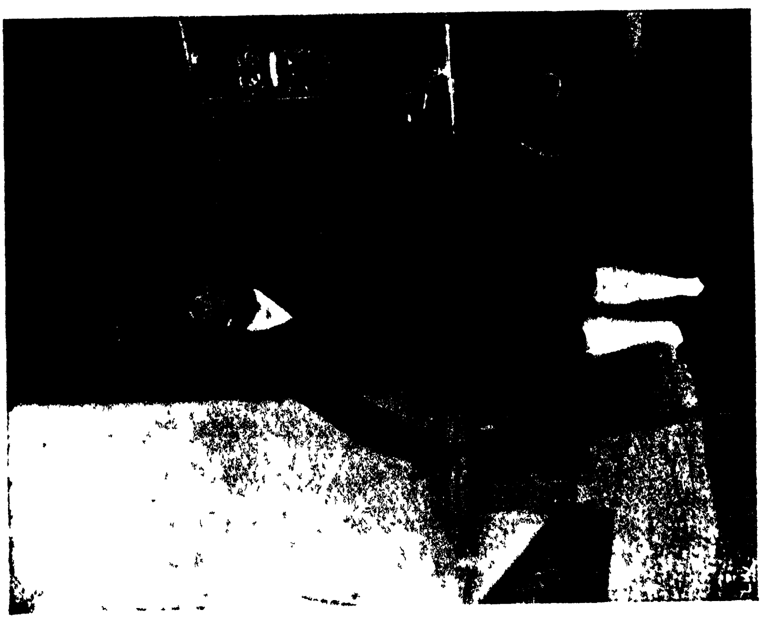


Fig. 259.—A Royal Exchange Fireman (1791).

In all drills and duties, care should be taken to see the "slackers" do a fair share of the work. They are to be found in all communities, and should be cleared out, or they will be sure sooner or later to cause dissatisfaction amongst the good men.

Orders should be given in definite and clear terms, and at once obeyed, and on no account should a man leave his post or work unless instructed to do so by an officer.

Unnecessary orders should never be given.

An officer should treat all persons with civility, and should upon no account show preference for any particular individual; but good work should be judiciously acknowledged.

Smoking should not be allowed on duty, the only exception to this rule being when returning at night from a fire some miles from the fire station. Smoking in the engine room must be regulated by the position of the petrol store or the motors, if any.

The difference between the work of a well-drilled and disciplined brigade at a fire, and that of a slovenly one, is so marked that the most unobservant person cannot but notice the difference.

The Clothing of firemen should be strong enough to turn a jet of water, and lined with a woollen material and of a dark colour. It is essential that the tunics, trousers, and boots should be loose, but at the same time they should fit well. Firemen should be able to do gymnastics in their uniforms, and should not be trussed up in tight garments. This is most important.

The Professional Fire Brigades' Association, and the National Fire Brigades' Association, issue details of the uniforms adopted by them, which are the result of many years' experience.

Old uniforms, see Figs. 257, 258, 259, and 260.

The Helmets may be of brass, leather, or strong felt. The brass helmets used by the London Fire Brigade give a fair amount of protection considering the weight, $2\frac{3}{4}$ lbs. (1·2 kg.) when new. The advantage of brass is that firemen can readily be distinguished from the police and other persons.

The London pattern is so designed that the peak shades the eyes without unduly interfering with the view, and the curtain at the back protects the neck and ears from molten lead, etc., without obstructing the hearing of the wearer. The chin-strap also acts as a protection to the side of the face, and yet the helmet is sufficiently narrow to allow a man to pass through the space occupied by a door panel. The height of the skull part above the head allows a good air space between the metal and the head; this space is ventilated by holes in the front of the comb.

The comb projects in such a manner that, should a man fall, the front of the comb and the peak strike the ground before his face touches.

The brass of the helmet is carried upon a leather lining which fits close to the head, and is vandyked, and the points joined by means of a lace, so that, in the event of a blow, the weight of such blow must first cause the breaking of the leather, the bending of the comb, and the turning up of the curtain upon the neck before the base of the skull is affected.

Leather Helmets, weight 2 lbs. (0·9 kg.), are if anything stronger, and last longer than brass ones, but, owing to their rigidity do not act as a buffer by partially collapsing upon receipt of a blow. An old fireman's hat is shown in Fig. 261.

Felt Helmets are lighter and of many patterns, varying from that worn by the police, with comb, to the tropical sun helmets in dark felt.

Badges.—As mentioned above, the Firemen's Associations have made regulations as to uniforms and badges, but for simplicity the London rule can be applied to any brigade.

Firemen.—Double-breasted tunic with two rows of brass buttons and badge with number on left breast. Axe and pouch, spanner and pouch.

Sub-Officer.—The same with a single epaulette of brass without the side pieces, on right shoulder.

Station Officer.—Same with one brass epaulette with side pieces, on right shoulder.

District Officer.—The same with two brass epaulettes, no badge.

Superintendent.—Single-breasted tunic, one row of brass buttons, and two brass epaulettes.

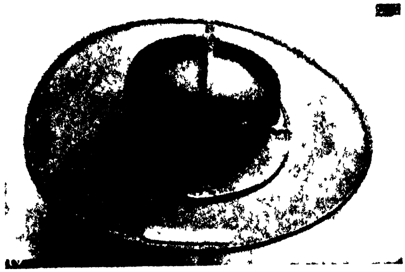


Fig. 261.

Fig. 262.—Austrian Fire Brigade Helmet.

Chief and Principal Officers.—Single-breasted tunic, one row of silver-plated buttons and two silver-plated epaulettes.

Helmets and belts are all of the same pattern, except that the superintendents and principal officers have patent leather belts and axe pouches, and further the buckles and helmets of the principal officers are silver-plated.

Belts are 2¼ inches (0·06 m.) wide, 48 inches (1·22 m.) long, with a strong brass buckle 2¾ inches (0·07 m.) wide and 3½ inches (0·09 m.) long, with rounded corners.

The weights are :—Belt 1 lb. (0·45 kg.), axe pouch ¾ lb. (0·34 kg.), spanner pouch ¾ lb. (0·34 kg), axe 1¾ lbs. (0·8 kg.), spanner 1¼ lbs. (0·57 kg.) ; total 5½ lbs. (2·5 kg.).

In addition to the above, a pocket line of three stranded hemp, 12 feet (3·66 m.) long, weighing ¼ lb. (0·12 kg.), is carried upon the belt or in a pocket. A fireman with this equipment should have with him sufficient gear for all ordinary purposes.

Brigades that have to travel long distances should be provided with some protection against cold. A long cloth or oil-skin cape for each man and one strip each side for covering the knees has been found an excellent cover, as it will retain the heat of their bodies for a long time.

Health.—The health of firemen is a very important matter.

Firemen are mostly selected from men of good physique, and pass an examination by the brigade surgeon. If they are not exclusively employed as firemen, their ordinary employment should provide exercise to keep them in health. Even then a certain amount of gymnastic and general exercise is necessary.

Professional firemen suffer from the effect of long periods of inaction and short bouts of extreme exertion, which in time will reduce the most robust to a state of lassitude, unless by constant drill and exercise the body is kept fit.

Firemen are also subject to pulmonary and rheumatic affections through exposure to alternatives of extreme heat and cold.

Firemen who will take the trouble to "keep fit" can in most cases do so. The following notes may assist:—

Do a set amount of general exercise daily.

If you think you have strained yourself, go at once to a doctor. The strain may be of no moment, or may be serious. Rupture is easily caused.

Change wet clothing as soon as possible, rub down briskly with a rough towel, and be careful not to put on damp clothing, socks, or boots. Then keep warm by exercise if possible.

Milk and soda-water, and plenty of it, may be taken in cases where poisonous fumes have been inhaled, but in all such cases a doctor should be consulted.

See that the duty rooms are well ventilated and do not allow the temperature to get above 60° F. (15·5° C.).

Have the fire boots large enough to take two pairs of socks, one thick and the other thin. By soaping the inside of the socks chafing will generally be prevented.

Leather boots should never be placed near a fire to dry, as the leather will be damaged beyond repair. Boots can be dried quickly by being suspended in a draught, or by filling them with barley-corn or oats. The corn soon absorbs the moisture. By drying the corn after each occasion it can be used many times. It is well, however, to ensure that the grain is all removed before putting on the boot.

In case of smoke or foreign matter causing trouble with the eyes, put the face into clean water, open and close the eyes several times, afterwards keeping them open. Upon no account rub the eyelids.

The vibration caused by the velocity of light is very injurious if the light is allowed to shine directly upon the eyes. Arrange the work so that all illumination is from the rear or sides.

Pay and Pensions having now become not only a political but a party question, the author has withdrawn his remarks upon this subject.

First-Aid has been so ably and exhaustively dealt with in "First-Aid in the Fire Service," by the late William Ettles, M.D., etc., and the "British Red Cross Society First-Aid Manual, No. 1," by James Cantlie, M.A., M.B., etc. (both of which can be obtained at a very small cost), that any attempt

to include in this book, even a *résumé*, would occupy more space than would be warranted.

The Treatment of Burns.—Most of the early books upon first-aid recommended carron oil (equal parts of either linseed oil or olive oil and lime water), or, if not at hand, some other oily substance, as a dressing for burns. Should oil not be available, dust the burnt part with a thick layer of flour, or some such material. Later, picric acid dusted into lint bandages was introduced. The bandages for storage were carefully wrapped in impervious paper, and when required sufficient of the lint was cut off, moistened with water, and applied to the burn.

During the War (1916) a new treatment of burns, called "Ambrine," was practised in France with great success. A similar product is now used in the Army Medical Service, known as "No. 7 Paraffin," with satisfactory results.

It has been found in practice that great care is required in the preparation of the paraffin so as to obtain a standard product that can be relied upon. The British Fire Prevention Committee have taken considerable trouble to obtain suitable wax and the necessary accessories for applying the treatment, and have arranged for self-contained outfits, in three sizes, under the name of the "Burnol" Brand of "No. 7 Paraffin."

The treatment consists of gently drying the burnt area, and then coating with the liquid paraffin at a temperature the patient can bear, probably about 130° F. (54·4° C.)—*i.e.*, just before the wax shows signs of a solidifying film upon the surface. Full details of the method of using are given.

It must be remembered that in all cases of severe burns a most important point to attend to is the treatment of shock; this can be done by applying warmth *without* and giving hot fluids to drink. Never allow a patient to be conveyed upon a stretcher after a severe injury, without being properly covered up and kept warm.

"A fireman who has sedulously devoted himself to the necessary study and labour, and has made any fair success, may well be proud of his profession, but he must never forget that he has colleagues in his work—the architect, the merchant, the manufacturer, the designer, the mechanic, the chemist, the electrician, the hydraulic engineer, and last, by no means least, the population, whose care or want of care most seriously affect the general result.

"Sometimes the fireman may give the foremost place to one of these, sometimes to another, sometimes perhaps to himself, that is if he is somewhat unwise and inordinately vain; but there can be very little doubt that in the great centres of commerce and manufacture and population, the general condition of the place with regard to its safety or danger from fire depends on many causes which are inextricably mixed together. Unless the architect erects good buildings, the merchant puts into them a safe stock, the manufacturer takes constant, thoughtful precaution in his work, the designer prepares, and the mechanic constructs suitable appliances, the chemist devises measures to guard against spontaneous combustion, explosive compounds, and inflammable vapours, the electrician furnishes means of rapid communication, and also (as may be hoped in the very near future) a mode of safe lighting, the hydraulic engineer supplies water, and the population takes reasonable care to prevent fire, and, when it does happen, to send

quickly for help, unless all these carry out to some extent their several functions, what can the firemen do? It is true that in most of the cities of the Old World, and notably in some of the largest, he has to fight against neglect in all these points, and there he is no doubt at disadvantage; but he knows the danger thoroughly, and does not fear them, and this is something. The public also know them in their own way—in many cases exaggerate them—and when a disaster happens, are not in the habit of blaming the fireman, and this also from a certain point of view is most important.

"Before going further, it must be frankly stated that there will be no detailed allusion in this book to the romance of the profession or the personal courage of those engaged in it. There is some romance in every kind of active life; but this is chiefly known to the spectators, not those who have to do the work. Courage can be found everywhere; but it varies much, and a complete analysis of it would require an essay to itself. Two men may do the same act, perform the same feat at the same time, under circumstances precisely similar in every respect, and yet the measure of their courage may be widely different. One does it in the stern discharge of duty, thoroughly knowing the danger, but not flinching, the other under an influence which may be called excitement, knowing the danger only partially or not at all. To the ordinary observer both deserve equal credit, but viewed by the light of practical experience the difference between the two is great. This is one of the numerous pitfalls in the way of a beginner, and unhappily there are many cases of weaklings tumbling in, never to rise again.

"On the other hand, the strong occasionally avoid doing publicly something which they know ought to be done, which though dangerous they are not afraid to do; but they avoid it all the same, in order that they may not seem to act for the sake of mere applause, which they consider worthless and despise accordingly. Thus it will be observed that in the fierce light that beats on an unfortunate fireman a second kind of courage is required. Most of his work is necessarily done in public, and if he wants to do it well he must show moral as well as physical courage; in short, he must harden his heart and act as if no one were looking on. The true test of a good man is that he looks for approval only to his own superior and his comrades, and takes the applause of spectators at its real value, as a mere expression of personal kindness and appreciative gratitude for the performance of labour under difficulties.

"The best advice which can be given to those commencing is to go slowly, avoid enthusiasm, watch and study, labour and learn, flinch from no risk in the line of duty, be liberal and just to fellow-workers of every grade, not only to the humble, but those in the highest places, who need liberality and justice most, take care not to wear the spurs before they are duly earned, and when they have been earned, wear them with humility, remembering always that those who have the largest experience in extinguishing fires, frankly acknowledge that they fall far below their own ideal."—*Shaw*.

Causes of Death.—In 1912 the Register-General issued a note in the "Manual of the International list of causes of death as adopted for use in England and Wales, based on the second decennial revision by the International Commission, Paris, in 1909," asking that the headings of the

mortality tables should be upon uniform lines, and indicated that those dealing with fires, etc., should be classified as follows:—

166. CONFLAGRATION.	Burn by petroleum.
Conflagration (to include all injuries).	Burn by sulphuric acid.
Crushed at fire (conflagration).	Burn by vitrol.
Fire (in sense of conflagration).	Effects of radium.
Inhalation of smoke (burning building).	Effects of X Rays.
Jumped from burning building.	Explosion of lamp.
Suffocation (burning building).	Lamp accident.
	Scald (of any part of body).
167. BURNS (conflagration excepted).	Scald by boiling liquid.
Burns (not conflagration).	Scald by boiling water.
Burns (of any organ or part).	Scald by drinking hot liquid.
Burn by corrosive substance.	Scald by steam.
Burn by fire.	X Ray dermatitis.

See an extract from Dr. Brouardel's Report, Chap. XVIII.

Medals and Rewards are now so abundant that the value of decorations as a whole has considerably decreased during the past few years, and the bestowal of medals by local authorities upon members of their fire brigades has simply an additional tendency to familiarise the public with the lavish display of decorations.

It is known that the hope of reward sweetens labour, but rewards of whatever kind should only be made to indicate work far above the ordinary duty of the recipient.

The duty of a fireman is a noble one when carried out with the single idea of benefiting the community, but it is debased if his first thought is of what he is likely to make out of it.

Wearing two or more types of the same medal or badge should never be allowed.

The public rewards available for firemen are :—

Albert Medal.	
King's Police Medal,	For acts of exceptional courage and skill or for conspicuous devotion to duty.
Royal Humane Society,	Medals and Diplomas.
Carnegie Hero Funds,	Diplomas and money grants.
Society for the Protection of Life from Fire.	Medals, certificates, and money grants.
London County Council,	Silver medal for extraordinary bravery at fires.
	Bronze medal for 15 years' service with zeal and fidelity.
National Fire Brigades' Association,	Bronze medal for 10 years' active service, and bar for each additional five years.
	Silver medal for 20 years', and bar for each 5 years after.
Association of Professional Fire Brigade Officers.	Bronze medal for 15 years' clear service.
	Meritorious Medal.

CHAPTER XV.

GETTING TO A FIRE—HOW TO ATTACK A FIRE—RETURNING FROM A FIRE—SALVAGE WORK.

Getting to a Fire.—Next in importance to obtaining information of or a call to a fire is to get there—of course, to get there in such a condition as to be able to carry out quickly and quietly very arduous work. It is, therefore, proposed to review a number of questions that bear upon this subject.

A brigade officer who takes an interest in his work will not only know practically every building of his immediate district, but should be well acquainted with the surrounding country, know where isolated mansions or farm buildings exist, and generally the condition of the roads or tracks leading thereto.

The excellent ordnance maps that can be obtained should be consulted periodically and have noted upon them any information gathered first-hand or from residents in the various localities. It is of little or no use for enthusiasts to rush off with a hose cart for a mile run at a sprinting pace and to be dead beat on arriving at the fire. Again, it must be remembered that horses can only travel at a quick pace for a limited distance, and every foot of rise in the ground causes an enormous amount of extra energy to be used. In going up inclines of any length everyone with the exception of the coachman should dismount and walk, and possibly assist by pushing at the worst places. On arrival at the top of the rise it is a good plan to stop altogether and give the horses plenty of time to regain their wind. To some persons it may seem absurd to see firemen standing about when going to a fire, but the outcome of the rest will enable the horses to complete the remainder of the journey, and, in fact, cover the whole distance in much less time than if they had struggled on in distress.

Even motors have their limitations. The greatest care is necessary to prevent any undue forcing of the pace, particularly on rough roads, causing heating of the tyres, and very likely an absolute breakdown of the machine. It must be remembered that motors weighing 5 tons or more will not travel over soft ground, as the wheels soon sink in, if not to the axles, as far as to the underside of the tool box. It is, therefore, considered necessary to draw attention to the following, which may to some extent appear elementary.

Motor Accidents.—One of the most difficult matters to determine in cases of accident is the pace at which the appliance was travelling, as in the absence of a recording speedometer it is almost impossible to get two persons to agree on the pace. In the case of accident, the position of the vehicles and both their back and front wheels should, if possible, be marked at once on the road and measurements taken if possible, by certainly not less than two, and better still by three, persons.

Maps.—All maps are, or should represent, the horizontal distance from place to place at right angles to the diameter of the earth, and, therefore,

the gradient of the roads leading from the fire brigade station should be plainly marked with arrows indicating the gradients, as shown in Fig. 263.

Fig. 264 shows at a glance the great difference in distance between the surface of the ground on an incline and the horizontal distance.

Under recent action of the Roads Board the majority of the main roads in the country have been greatly improved, but village highways and byways may be in a very worn condition. often with ruts; and although they could be used by horse-drawn appliances, a motor could not pass two yards over them.

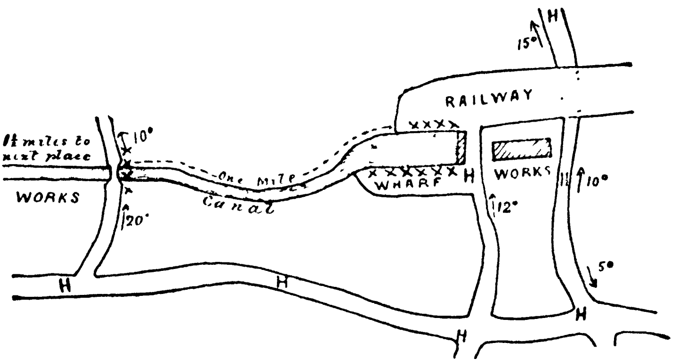


Fig. 263.

A note of the various types of road have to some extent been taken by such organisations as the Cyclists' Touring Club, and later by various motoring associations and classifications made by them. Simple marking by coloured or dotted lines (six kinds are shown in Fig. 265), on the map should readily enable the officer in charge to make up his mind which is

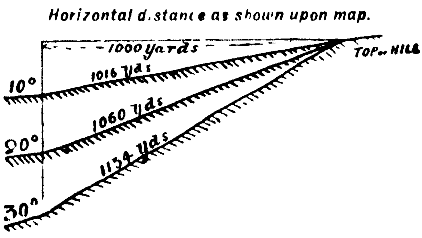


Fig. 264.

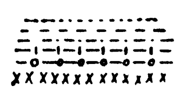


Fig. 265.

the better way to approach his destination, always remembering that it is not the fire but the water supply to which he has to take his machine, and that the nearer the pump is to the surface of the water the better will be the result of the working. The reason for this is set out on p. 344 of Chap. XI., when dealing with suction efficiency.

In country districts it was found to be useful to send a man on a bicycle immediately on receipt of a call to spy out the land, or rather the water, and choose the best position for the pump. In the present day of mechanical appliances a motor cyclist could do very valuable work in getting away

and, if possible, returning to meet the appliance with the necessary information.

The 6-inch county maps are sufficiently large to show the position of ponds, rivers, and other sources of water supply, which by a little attention and care can easily be amplified by notes and sketches, particularly as regards those which are in the vicinity of premises more or less isolated.

Special attention should be given and a note made as to the state of the supply in *dry weather*.

In urban districts it is equally important that the access to the water supply should be carefully investigated, and the largest maps of that particular part used to denote the entrance to canals, rivers, or docks or enclosures where the most accessible water supply may be obtained.

Rivers and canals are useful sources of supply, provided they are accessible. It is often found impossible to get to work directly from canals from the public roads, as the canals are usually bordered by wharves and private property. Very few owners of such would object to the fire brigade making a preliminary survey of their premises, and in many cases would welcome a drill in their locality to test the availability and utility of their protection. It may also be noted that the members of the brigade remember instances of this kind for many years, and should necessity arise would recall what they had done on a previous occasion at a drill.

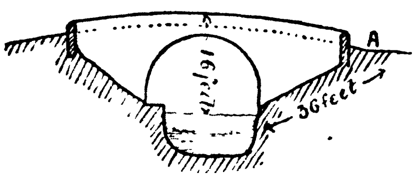


Fig. 266.

A small portion of a map is given in Fig. 263, and the xxxx show the only part of the canal bank upon which a pump could be got to work. The public hydrants marked H are as a matter of course upon the highways only.

Fig. 266 is a sketch of the bridge over a canal, showing that 36 feet (11 m.) of suction with 13½ feet (4·1 m.) lift would be required if a pump were worked from the position A, and 20 feet (6·1 m.) of suction with 16 feet (4·9 m.) lift if worked from the centre of the bridge.

The previous remarks with reference to canals apply equally to rivers, but special care is required when dealing with tidal waters. Always remember that the suction pipe should be kept at the shortest possible length. See notes on p. 344, Chap. XI.

In cases where it is impossible to get an engine sufficiently near to a pond or stream to use the suction, an old-fashioned method can be adopted. Form two lines of people from the source of supply to the dam out of which the engine draws its water. Buckets are filled by a man who hands them to the first of a line of men, who pass them from hand to hand up to the engine or dam, into which they are emptied. The empty buckets are returned to the water by another line to be refilled. The return line may be composed of women or children, as the labour is light.

In laying out a water supply for a town, engineers usually calculate and determine the capacity of the pipes according to the maximum daily consumption.

In some cases, as in districts occupied by dry goods warehouses and similar trades, the actual consumption is very small, and in many cases the Water Authorities do not feel justified in laying pipes of large enough dimensions to give a good supply in case of fire. Many areas originally consisting of small residential property have had factory buildings erected in their vicinities in order to obtain the necessary labour for their works. Again, districts with good houses and gardens in the rear may have had the gardens reduced, and practically the whole of the central portion between the two rows of houses appropriated to the erection of workshops or timber stores, while the water supply has remained in its original state. Where in residential districts it might only be necessary to get one or at most three hydrants to work at any one fire, that number would be inadequate in dealing with a large workshop or timber fire as mentioned above. The outlets of hydrants should not be less than 2 inches. Particular attention should be paid to the volume of the supply in order that a fair number of hydrants may be usefully employed in case of need. It is a question for many water engineers how this can best be done without going to the expense of relaying the whole system. One of the easiest ways to overcome the difficulty is to run additional mains to the supply at various points and also to connect up the mains one with another, so that the system is formed of complete rings without any dead ends.

Horses, when standing after a run to a fire, should be protected from the cold, and, if possible, stabled.

How to Attack a Fire.—Upon arrival at a fire, much depends upon the ability with which the responsible officer grasps the situation.

Enquiries should be made as to whether anyone has been injured, or if any persons, or animals, are still upon the premises, and if so immediate action should be taken to rescue them. In any case the premises should as far as possible be carefully searched.

The importance of taking up quickly a good position at the water cannot be too much impressed upon the officer. At tidal rivers, it should be noted if the tide is flowing or ebbing. He should give instructions for the appliances to be connected with the nearest water supply and the hose made ready while he himself makes a rapid inspection of the scene of the outbreak. He should particularly note the direction and force of the wind (see Beaufort's Scale of Wind Force in Appendix), but he should lose no time in this, and should be able to point out the position for the first branch by the time the hose is ready. From this position he should be able to concentrate a direct attack on the most vulnerable part of the fire. A fire must be fought and not followed. By this is meant that the most effective position from which to do good work is on the lee side, or the side towards which the fire is travelling. It is sometimes the best policy to damp down the combustible surroundings endangered by the radiated heat and flames (see p. 42) before actually attacking the fire, but it is quite impossible to lay down hard and fast rules applicable to all cases, for hardly any two fires are alike, either in their scope or size. It is safe to say, however, that in all cases the foregoing principle of going straight at the fire must be followed, though much of the subsequent action depends on the nature of the outbreak.

All fires have something in common, but there is much that necessitates a difference in the method of handling. Hotel fires, for instance, can hardly

be compared with those in warehouses or ships. Their differences are obvious, and consequently the use of the fire appliances may be modified, while many special tools may be found necessary. In hotels it is possible that the appliances for life-saving may be invaluable, especially if the fire occurs at night, while, at a warehouse fire they may be of little use, except as ladders affording means of access.

The officer in charge may form the opinion that the fire threatens to extend, and that additional assistance will be necessary; he should then detail a messenger to acquaint his depôt, or that of a neighbouring brigade, with his wishes, and should give a rough idea of the nature of the fire and how much assistance is required. This can best be communicated through the fire alarm system or public telephone, but if, for any reason, these are not available, he should invoke the aid of the Police. In cases where important messages have to be sent by casual or unknown persons, it is well to dispatch them in duplicate, each messenger independent of the other, but both messages *identical and in writing.*

It cannot be too strongly impressed upon fire brigade officers that it does not show any weakness on their part to ask for additional assistance, even if the after events should prove that such assistance was unnecessary.

Supposing that the request for assistance is not complied with, the responsibility for a more serious conflagration with its attendant consequences would not upon this point be held to rest upon the officer in charge of the fire. Upon the arrival of outside assistance, the officer should remember that by Sec. 89 of the Public Health Amendment Act, 1907 (see Chap. II., p. 54), the control of all operations for the extinction of the fire remains in the hands of the local officer, and he should be ready to instruct the newcomers what positions to take up and what duty he wishes them to undertake.

In large towns with brigades of a considerable *personnel*, a selected number of men should be trained to act as orderlies or messengers, and should be provided with a brassard made to fasten to the left arm, in order that they may be readily distinguished by the subordinate officers, who will accept their messages as authorised, and who will not call upon them to undertake other work. These men should accept messages from their seniors for the officer in charge of the fire, to whom they should personally report. All verbal messages should be as concise and explicit as possible. Human nature being what it is, the chief officer should be familiar with the mental capacity of his subordinates and know how to appraise the information he receives. A request for more assistance from one man may be ignored for a time, while the same from another must be acted upon at once. All messages should contain definite information, such as . . . wall has cracked for . . . feet on the top or side; . . . men required; . . . feet of ladder or . . . lengths of hose required; never use the words "some," "possible," or "available." In case of large appliances being asked for, an indication should be given of the best direction for them to approach their position.

In cases where it is necessary to communicate with the officer in charge from positions out of hearing, such, for instance, as the roof of a high building or across a river, the Morse Code is often used by means of the arms alone, but in order to reduce the time occupied in spelling out the message, Fire-

master Pordage, of Edinburgh, has compiled a code of signals in which the use of two or three Semaphore letters represent appliances in constant use, while special attitudes are used for important signals, such as "more hose required," "all hands wanted," etc.

Careful officers soon know and appreciate a ready response to requests they send, and will use every endeavour to make the most of the instruments at hand. At a fire covering a considerable area it is well to fix upon some central position as a temporary headquarters, and while the officer in charge must move about from time to time to ascertain definitely by personal inspection how matters stand, a responsible man should be left at the central position, who will be able to receive messages and direct inquiries. The moral effect of the presence of the Chief, with a few cheery words of encouragement at any uncomfortable or dangerous position that has to be defended, is enormous.

Each officer or man should understand and feel that upon his individual efforts the success of the whole operation may depend. Many cases could be quoted where the work and example of one man has greatly curtailed a fire.

It is of the utmost importance for each fire brigade officer to become acquainted with the nature and distribution of buildings, fire-risks, water supply, etc., within the area protected by the brigade of which he is in charge, and thus be able to explain to others the readiest way of obtaining water and the most expeditious mode of getting to work with the best effect. In the case of large buildings it is often difficult even for firemen to find their way about, and when the rooms are enveloped in smoke it is dangerous. Not less than two men should work together in thick smoke. If any doubt exists as to the stability of the floors, the leading man should have a rope attached to his belt. The above is one of the reasons why the fire brigade officer should have, at least, a joint executive power with the local authority in seeing that all buildings are as far as possible protected against fire and provided with proper means of escape for all workers and inmates.

The officer in charge should from time to time confer with the Chief Police Officer present, in order that proper precautions may be taken to divert traffic, to keep the public at a safe distance, and generally to afford facilities for the rapid operations of the brigade. This may involve the clearing of houses or dwellings of their inhabitants, but as a rule the removal of furniture and merchandise is deprecated, on account of the great damage usually sustained in hurried removal, and the strong inducement offered to pilferers.

Special care is necessary where animals or vehicles are to be removed. Animals are easily excited in the presence of fire. In order to obviate any difficulty, it has been found that if the regular stable men will harness the horses quietly in the usual manner, and then gently place a covering over each animal's head, so as to blindfold it, they can be led out of almost any difficult situation.

Perhaps it might be well again to emphasise the fact that the actual seat of the fire must be discovered and the water directed thereon. For fireman to be successful, they must get in below, above, and on every side of a building. Their whole success depends on getting in and remaining there, and they must always carry their appliances with them, as without them they are of little use.

It may, however, be necessary, particularly in the early stages of a fire, to get what is called a "checking branch" to work from the street level. This consists of a branch brought quickly into action as a temporary measure to check the fire until a line of hose can be laid towards the seat of the trouble. It should be so directed that it reaches some part of the fire, or it will be useless. When a direct hit cannot be obtained, it is often possible, by hitting the ceiling, wall, or some projection, to deflect the stream of water so that part at least reaches the fire, but this must not delay or interfere with the arrangements that are being made to attack at close quarters.

Smoke is, without doubt, the most serious obstacle that a fireman has to deal with, and cases have occurred in London in which the smoke was so dense and beat down so violently into the street, that nearly twenty minutes elapsed before the officer was able to ascertain from which building it emanated. Other cases have occurred where whole buildings of considerable extent have been completely smoke-logged from comparatively small smouldering fires in out of the way or inaccessible positions. It is in cases of this kind that smoke helmets are of such great value.

As soon as, but not before, the means of extinction (water, etc.) are ready at hand for instant use, openings should be made at the highest part of the building to allow the smoke and heated gases to escape. This is especially the case in warehouses where accumulations of heated gases are often met with in sections of the building filled with goods. These gases vary according to the nature of the goods stored therein. It should be certain that the water used is directed at as close a range to the actual seat of the fire as possible. A grave error is often made at fires by the indiscriminate use of water applied anywhere and everywhere. It is of little avail to play water into a building merely because a large volume of smoke is issuing therefrom. It is necessary to emphasise the fact that a stream of water will scarcely penetrate walls or roofs, and a jet of water that would have satisfactorily dealt with the fire is ineffective if interrupted in its course. Such interruption may be caused by the action of the wind or even paper that has partly dropped from the ceiling of a room in which there is a fire.

The size of nozzle to be used is important and is dependent upon the pressure from the pump or hydrant, the size and length of the hose in use, and the distance the branch has to be from the seat of the fire. Other things being equal, the largest size should be employed, so long as it effectually hits the fire. The tables on pp. 110-115 give the height and horizontal distances of jets under various pressures through different lengths and kinds of hose.

The duty of the Chief Officer of a Fire Brigade is primarily to defend the area entrusted to him against loss by fire. Property is equally destroyed even if water has done the damage instead of fire.

It is useful for brigades to practise with different-sized nozzles and pressures of water, and thus ascertain by experiment the most effective large jet and the number of small jets that can with advantage be obtained from their pump and the average hydrant supply.

In cases where a very long distance has to be covered, or a powerful jet is required, two, three, or more lines of hose should be used to a connecting breeching at the base of the branch pipe.

When defending a number of vulnerable points at the early stages of a fire, it is often necessary to bring into use a series of small jets, but for the attack upon a fire of any considerable size, small streams are useless.

In smoke-logged basements it is sometimes absolutely necessary to use a spray nozzle to cool the air and at the same time wash down the suspended particles of matter in the smoke. In order to ventilate rooms above ground level the windows should be opened at top and bottom, as by this means a better circulation of air is obtained.

In warehouses special precautions are necessary to ensure that no undue weight is added to the floors through the stock absorbing water, as it is likely to cause a sudden collapse of the building. This, to some extent, may be provided against by clearing runs for carrying off as much of the water as possible, which in turn necessitates attention being directed to the gullies, etc.

In ships and other floating craft, it may be necessary to haul off from the quay and away from other craft. The great difficulty with fires of this class—*i.e.*, fires in the hold of ships—is that, owing to the want of ventilation, great danger is encountered from the gases generated by the combustion of the miscellaneous material in the cargo. (See Fires in Ships, p. 207.)

The officer in charge having mustered and disposed of his forces to the best advantage, and having seen that the water supply is adequate, etc., must not forget that supplies of fuel and consumable stores will soon be necessary, and that possibly some of his men may need relieving, especially where they have been having perhaps a very uncomfortable time from the smoke, water, and dirt. A good officer makes every endeavour to preserve the physical fitness of his men under all conditions. Should a man appear to be somewhat overcome by the fumes, he might be drafted, say, from an internal to an external duty, and his place taken inside the building by one of the men from outside. If the fire is likely to last some time, and especially in the night-time, refreshments should be provided. Nothing is perhaps more welcomed by men working in smoke than a good drink, good coffee being the best stimulant. Should any of the men be injured, they should be speedily removed for medical attention.

After the men have settled down to hard fire-fighting inside the building it is often necessary for the operations to be changed from a direct attack on the building itself, to an endeavour to preserve the surrounding property. This may be necessitated by a change in the direction of the wind, the fire reaching some readily combustible material, such as chemicals, or the building itself showing signs of weakness. When this time arrives it will not be long perhaps before the internal attackers realise that they are in danger themselves, and they must, therefore, be drafted to new positions until, when the collapse of the building is imminent, they should be withdrawn altogether and should join forces with those outside, and aim at keeping the neighbouring property safe.

Some brigades have in their organisation a system of signals by whistles in which the "retreat" forms an important call, but all such wind instruments are very liable to be misunderstood and cause disorder. A lusty shout: "All out" is well understood, and can readily be repeated from man to man, until it reaches those at the far end of the building or in cellars.

It may sound somewhat paradoxical that the firemen should turn their

attention to other places than those actually on fire, but in practice it is often found to be the soundest policy. When the roof of a building on fire has collapsed it often provides a further opportunity to renew the attack directly at the fire, for so long as the roof remains, a strong current is set up which seems to nullify all the efforts of the firemen. In fact, it is a common experience that the roof acts like a closed damper, whipping up the fire to an intense heat.

The proper and efficient illumination of fires and their surrounding is important, not only for the firemen to find their way about, but to indicate dangerous places.

For immediate and outside use a large "Bengal light" can be used; they are made from 3 to 4 feet (1·5 m.) in length and 1¼ inches (0·032 m.) in diameter. The casing is of thin zinc, and readily burns with the light. The ends are fitted with a small detonator, so that all that is necessary to bring them into use is to give the head a sharp tap upon the paving or some other hard substance. These give a powerful light for a short time.

Large wax torches 1¼ inches (0·032 m.) in diameter and 3 feet (1 m.) in length are much used on the Continent for fire work; they have a hole down the centre to assist the combustion, give a very fair light, and are fitted at the end with a small steel pin; this pin will support the torch when placed between the joints of stone paving or when forced into a wooden floor.

Small sealed tins containing 1 lb. (0·5 kg.) and upwards of carbide of calcium, with tops secured by soft solder so that the cover can easily be stripped off the burner, and having a hole in the bottom, are handy, as all that is necessary is to place them in a bucket of water and apply a light to the readily generated acetylene gas. Some of this type about 12 inches (0·3 m.) long are fitted with a charge of magnesium in a small chamber near the burner; this magnesium is ignited by water, and, as it continues to burn for some time, will re-ignite the acetylene gas, should, as is often the case, the acetylene jet be extinguished by a jet from a branch. This size will give a light for about one hour.

Acetylene lamps using a charge of from 14 lbs. (6·4 kilos.) to 28 lbs. (12·7 kilos.) are useful for long winter nights, as they will burn six or seven hours, and can be recharged at pleasure. These, and also small ones of the same pattern can be fitted with reflectors to project the light on to any required spot.

Petrol-driven motors can be fitted with dynamos to generate sufficient electric energy to supply arc-lights. These arc-lights can be worked at considerable distances from the motor, if provided with proper waterproof cables.

The old copper colza-oil lamps are fast going out of use on account of the difficulty in keeping the oil in such a condition that it will give a useful light, and the danger of taking them into buildings charged with gaseous vapour. Many kinds of electric hand-lamps are now upon the market, fitted with batteries that will give a light for some hours and show a light on any position.

Again, it must be forcibly impressed upon the minds of firemen that to do good work at a fire the water must be projected direct upon the seat of the burning material, and the greater the force of the water the more

effectual will be the result. In order to ascertain the most vulnerable place to attack, great experience and judgment are required; therefore, all branches should be under the immediate charge of a senior fireman. In London the place of the officer in charge of each appliance attending a fire is at the branch attached to his engine or pump. From this point of vantage he can see if he is getting a proper supply of water and how far the section of the building is safe, and by sending messages by one of his men, keep the officer in charge of the fire informed of the progress or otherwise of their work. A judicious officer will place his men in such positions that material falling will do the least possible harm to his little force; on the Continent senior officers often undertake this duty.

In practice it is found that small overhead projections make a good cover, such, for instance, as an opening in a 9-inch (0·23 m.) wall. If the opening is provided with a good arch or lintel, it will be found a comparatively safe place, even if the upper part of the wall should fall.

In passing under floors a glance at the joists will show how they are supported, or their direction can be ascertained from the way the floorboards are laid—viz., across or at right angles to the joists. The joists are usually about 12 inches (·3047 m.) apart, so that in cases where the floorboards are seriously damaged, it is often safe to walk upon the floors if the feet are turned well outwards, as by this means much of the weight of the body is immediately above the top of the timbers.

Firemen entering a room full of smoke should test the floor by keeping their weight upon one foot while the other is pushed forward with care until a firm standing place is found from which to take the next step, otherwise an accident may occur by falling down a trap door, staircase, or hoist. If the hands are held loosely in front when passing through dense smoke many collisions with obstructions can be avoided.

Remember that, as air is heated, it will ascend and the cold air from outside will take the lower stratum, until in its turn it becomes heated and ascends. Therefore, a man may remain in a room heavily charged with smoke by creeping along the floor. Often from such a prone position he may be able to see some distance, and possibly locate the fire or see burning particles falling on to the floor; in such a case he should have a good idea of the place to direct the water.

A fierce fire may be tackled at close quarters if a spray of water is allowed to fall upon the men, wet their clothes, and keep down the temperature of the air immediately adjacent to them. In nearly all cases the jet of water will create a draught and thus cause a supply of fresh air, to follow the hose, sufficient to provide the necessary quantity of oxygen to allow the men to carry on.

Back draught (so-called) is the sudden ignition of inflammable dust in the air caused by organic substances that have become heated by fire. Owing to the lack of oxygen combustion is delayed until a window is broken or a door opened. When the inrush of cold air containing its oxygen causes the sudden ignition of the heated air and an outburst of flame with such force as to give the effect of an explosion. The force of such rapid burning has been known to force out walls. A dense mass of black smoke is usually seen issuing from the building a few moments before an outburst of this kind occurs.

At last comes the time when either the fire has been beaten or has been so confined that further conflagration is unlikely. Then the firemen receive the order to pack up and descend to the ground, the hose is coiled up, and all arrangements properly made for the return. But all the men should not return at once, for it is no uncommon experience for a fire to break out again after it has been left. In one unfortunate instance the fire actually broke out three separate times before it was finally extinguished. It is, therefore, the best policy to leave a care party to turn over the smouldering debris and watch.

In London, after a fire is extinguished the remains are handed over to the care of the Salvage Corps, as representing the Insurance Companies, but if the property is not insured, then to the Police. In some of the large towns the fire brigades act as representatives of the Insurance Companies, and undertake the duty of protecting their interests, and watch and clear up the premises to reduce the loss as far as possible. In any case, it is important that the officer of the fire brigade present should make a written note of the name of the person to whom he handed over, as serious questions upon the state of the stock and buildings may arise when the Insurance Assessor appears upon the scene.

Demolition.—During the whole time that a fire is in progress at a building of any extent, constant watch should be maintained on the structure for signs of weakness. The walls will often bulge outwards by reason of the expansion of the inner surface due to the intense heat of the fire.

Sometimes it is possible by the judicious application of water, to cool these inner surfaces, and thus restore a wall to its original position. At other times the walls become so dangerous that nothing but actual demolition is justifiable. Work of this kind naturally requires expert knowledge and great care, and where possible it is best carried out in small sections at a time, and under the direction of a responsible expert. The idea which is often prevalent of using explosives for this purpose should never be resorted to. The use of explosives, even by expert men who are skilled in the handling of them is unsatisfactory (as was proved at San Francisco), and the combustible materials in the demolished building will simply burn on the ground and the whole will be lost. It has been found also that the walls of buildings, if of brick or stone, make a far better fire stop than the space that they had occupied when standing. Black powder or low-grade powders, when used, invariably set fire to the buildings.

An exceptional case demonstrating the utility of explosives occurred at Midway Field, California, on the 26th July, 1919, during the drilling of an oil well, when the confined gas burst out furiously and the friction of the shale and sand caused the iron pipe to become so hot that it ignited the gas. The flow of gas was estimated at 100 million cubic feet per day, the flame was 200 feet high, and could be seen 80 miles away, and the roar heard a distance of 9 miles. The usual method of forcing steam, mud, and water to extinguish the flame was only effective for 50 feet above the ground, the gas above that height remaining alight. Ultimately, on the 5th August, by the combined use of steam from 20 boilers, water from 30 lines of 3-inch hose, 13 pumps, 100 barrels of Carbon Tetrachloride, and the explosion of 150 lbs. of dynamite, the fire was extinguished. When the charge of dynamite was exploded there was a deep red glow and a

black puff, and the fire was out for a sufficient time to allow the men to securely cap the pipe.

The efficacy of the mud jet has long been recognised in connection with the extinguishing of fires in colliery workings, but so far the method of applying and operating such jets has been far from efficient or scientific. One of the chief reasons for the success with which the mud jet usually operates is that it not only extinguishes the fire by means of its water content, but it cements all loose particles together and forms a cake over the gas-emitting openings, excluding the air and so making the mass safe for the future. Investigations have been made recently into the scientific side of mud-jet working, and it has been decided that the material of the mud, some of which should be of a lime and some of a clay character, should consist of sifted earth of 5 mm. mesh, boiler ash, dust from the cleaning of blast furnaces, and even combustible material, such as the refuse of coal washing, can be added to make up bulk without any risk should nothing more suitable be at hand. In the majority of instances the mud tank can be so placed as to operate by gravity, but steam or compressed air pressure can be used. It has been found that if a tank is placed at a height of, say, 15 yards, it will force the mud a horizontal distance of 150 yards, even allowing for fairly sharp bends in the conducting pipes.

"*Fire*" records a case of a pit fire which broke out in a German mine which was extinguished by flushing the seat of the outbreak with a mixture of sandy loam and water. The loam was placed in a trough, fitted with a worm conveyor, at the pit mouth, and the water sprayed on to it with a jet, the mixture being led down the shaft through a 4-inch pipe to the seat of the fire, which had been isolated by means of a barrier. The flushing was continued for six weeks, about 6,500 cubic yards of loam being used, at the end of which time the burning part of the mine was once more accessible. An examination of the coal showed that the loam had apparently formed a solid crust on the face, thus completely excluding air. To provide against further accidents of the same nature, which are not infrequent, a bore hole has been put down specially for conveying the flushing pipe down into the workings.

Returning from a Fire.—This chapter can very well be concluded with a few notes on returning from a fire.

If there should be a frost, bear in mind that running water does not easily freeze. Therefore, directly the pumps are stopped with the intention of making up, the men should be ready at hand and immediately uncouple the hose and with all speed empty it by "under running," and coil it up, otherwise in a short time, even a few minutes, according to the severity of the temperature, the hose will be so rigid that any attempt to move it will be well nigh impossible. The hose will soon be like a solid bar and easily broken (cutting the hose) if any force is used to pack it up.

Once having got it coiled, it can easily be removed to the fire station, where it should be properly thawed at leisure, as undoubtedly it will have become frozen in the coil. Do not attempt to uncoil it until thawed or the hose will be damaged.

Bearing in mind this precaution, the gear should be systematically collected and placed on the appliances in their respective positions, and the officer in charge must satisfy himself that all gear has been recovered and a record made of any damages that have been sustained.

Supposing some of the men are wet, as is very likely to be the case, hot coffee should if possible be served out, provided this can be done without detaining the men at the scene of the fire for a minute longer than is necessary. The issue of stimulants in the form of spirits should only be resorted to in extreme cases, remembering always that stimulants react upon the system, and if a considerable distance has to be traversed in returning to the station the men are very likely to take cold.

It is a good custom for brigades which have to travel considerable distances to be provided with long capes and a strip of oiled canvas to cover the men's knees.

On reaching a station the appliances must be at once restowed, and if possible fresh, dry hose obtained immediately ready for another call. Upon no account should this be neglected or the duty carried out in a perfunctory manner.

Where it occurs that the men have been subjected to exceptionally bad conditions at a fire either in thick smoke or have received minor injuries, they should be seen by a medical man, and if it is suspected that any of the men have inhaled acid fumes, even to a small extent, they should be immediately placed under the charge of the medical officer, who should have all the details explained to him. The action of acids on the system is not always manifest until some time has elapsed, with the result that the respiratory organs are so affected that recovery is often very doubtful.

In the larger stations it should not be difficult for the men left at home when the brigade is "out" to see that an ample supply of hot water is ready for the use of the men on their return, should they need a good wash down or bath.

Horses, after returning from a fire, should under no circumstances be put directly in the stable if they are begrimed and sweating. Indeed, one would hardly expect any good and humane person to treat an animal in this manner, but perhaps nothing is lost by repeating the advice that horses need very careful attention or they will soon show signs of indifferent treatment. They should be thoroughly cleaned and washed, covered with a cloth, and walked about until they are dry and cool. Horses should not be allowed to stand about at a fire and get cold.

Salvage Work.—Salvage duty at fires consists of making every endeavour to rescue property that may have been, or that may be, likely to suffer damage.

Salvage Corps are only maintained in a few large towns, and have their special equipment and plant. Elsewhere, as it is the duty of the fire brigades in every way to keep down the fire loss, it follows that protection of goods and buildings from incidental damage during and after a fire is important, and must be studied.

The articles used in covering goods and clearing up after a fire are as follows:—

Rubber-lined sheets 12 feet (3·66 m.) by 10 feet (3·05 m.) with eyelet holes at each corner and sides or tarpaulins, buckets, sponges, brooms, auger and handle, scoops, swabs, bags of sawdust, bag of nails, cotton waste, bag of corks, pair of electric wire-cutters, pair of gas tongs, padlocks and keys.

The above plant, with a supply of lanyards and rope, added to that usually carried upon the fire engines, will in most cases be found sufficient

for small fires, but a reserve should be kept at the fire station ready for the firemen to fetch to the fire if required.

Fires that occur in basements and lower stories of buildings invariably fill the upper part with smoke, more or less dense according to the nature of the burning material. At the earliest moment after the fire is in hand, and no more danger anticipated, the doors and windows should be opened to remove the air pressure, and the smoke allowed to clear away before it has time to penetrate into the fabrics or covers of the goods.

If the stairs are so damaged that the lower floors cannot be passed, it is usually possible to obtain an entrance through the roof from an adjoining building and work down floor by floor.

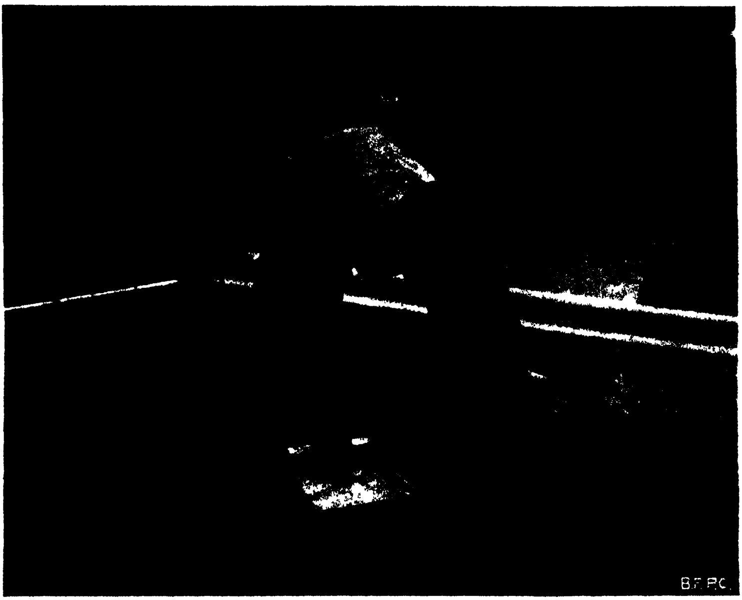


Fig. 267.

Water thrown upon boarded floors soon runs through the joints and is caught by the plaster ceilings under. Most ceilings are secured to the underside of the wooden joists by laths, and will carry a considerable weight before giving way. As the water has to be removed, it is usual to prick the ceiling from the under side, and thus allow it to drain away. Provision should be made to catch the water in receptacles, or to conduct it by means of the sheets out of the building. The "fire hook" or "preventer," which should always be found upon each pump or van, is the best implement for this work.

The water thrown upon a fire will, if it is not able to run away outside or to the lower stories, cause a considerable extra weight upon the floors, and, if the stock is of an absorbent nature, such as hops and rags, it will most likely cause the collapse of the building.

Each building may require a different scheme to clear it of water. Where there are drains, they should be kept clear, and it may even be necessary to open the ground and break a pipe to carry away the superfluous water.

Swabs are made of small, loose, hemp rope about 8 feet (2·5 m.) long, tied in the middle with a lashing, and having a cord through the bight to form a handle. Swabs are used to form dams upon floors, and can be jambed against doorways to turn water down staircases or in any desired direction.

Scoops are like strong dust pans turned up at the back to hold the water, and form a convenient grasp for the hand (see Fig. 267).

When no more water is expected, and after the floors have been swept and well mopped up, a coating of dry sawdust spread over the surface will absorb much of the remaining moisture and greatly assist in making the rooms fit for occupation.

After a fire much can be done to protect the building from further damage by providing temporary supports for partially burnt roofs or floors, blocking up doorways and exposed openings in walls and roofs. Tarpaulins are soon fixed over rafters.

It may be necessary to pull down walls or portions of buildings that are unsafe. As mentioned earlier in this chapter, demolition should be, if possible, only carried out under expert supervision.

Metal work of all kind must be thoroughly dried, cleaned and well oiled, and machinery turned round before being covered up after a fire. The water used in extinguishing the fire may not have reached the machinery, but the heat and steam-laden air most surely will have found its way and cause rust.

CHAPTER XVI.

PRIVATE AND WORKS FIRE BRIGADES.

UNLIKE public fire brigades who may be called upon at any time to deal with fires in a Church Tower, or a coal mine, the private and works brigades duty is, for the most part, confined to the protection of premises and goods in familiar places and of known extent.

Their principal duty is by constant vigilance to prevent a fire occurring, and at once to subdue any outbreak that may inadvertently be caused.

The requisite personnel for such a brigade must in all cases conform to the nature of the business carried on and the risks attendant thereto. A works employed in the manufacture of celluloid goods and explosive chemical substances should have a highly trained, scientific staff, with special appliances, while that required for a builder's yard could be composed of a few workmen with buckets of water.

It is difficult to impress on merchants and manufacturers what a total loss by fire may mean to a respectable old-established firm. It is not only the loss of goods, but the loss of trade, and trade connections that cannot be recovered, which may have taken a lifetime to build up.

The most successful Private Fire Brigade would be the one that never had a fire.

So important is the question of fire protection that the duty should be under the immediate supervision and control of one of the principals. It is often found that the departmental managers and foremen are so anxious to get the best return possible out of their section of the business that they allow risks to be taken with impunity that might be the cause of very serious loss of life or property.

The Chief Officer should, in any case, have constant intercourse with the principals and be responsible to them alone.

However loyal a fireman may be to his colleagues, and he should keep upon the best of terms with them, questions will arise upon some fundamental subject for which only those in high places can take the responsibility, and it is far preferable that the principal should have first-hand information.

The great necessity in all places of business is "good housekeeping." In a clean and tidy building irregularities are readily seen while a muddle will hide all kinds of erratic proceedings.

The Workmen's Compensation and kindred Acts have helped to bring home to many employers their liability for the safety of their workpeople.

The provision of proper means of escape, of doors opening outwards, panic bolts, the safety of the floors, and the protection of outside staircases from fire in the lower part of the building, are matters that should be approved and certified by the Local Authority, and in the case of factories, by the Home Office.

Causes of fire, means of suppression, and construction of building will be found set out at length in the various chapters in this book, and the B.F.P.C. Red Book No. 236 on fire prevention in an English factory may be consulted with advantage.

The duty of the private fire brigade is to see that all the safety devices are properly maintained in good order and kept clear, and to see:—

That doors are not obstructed by goods, cords, or irregularities of the floor and that they will properly fasten.

That the treads of the staircase are not slippery or worn, but in good order, and that none of the space is occupied by goods. (It is well to paint the edge of the steps white.)

That no projections, door-handles, etc., are allowed in any of the doorways, corridors, or stairways.

That a conspicuous notice is placed where any alteration is made in the height of riser, or width of the tread of any staircase.

That all exits are properly lighted.

That metal bins are used for all waste material and to secure its ready removal, sacks may be suspended inside.

That oily rags and cotton waste, new or in use, are kept in metal boxes and each machine be provided with this safeguard against spontaneous ignition. All bins and cans can with advantage be fitted with self-closing lids.

That any defects in the gas or electric system are at once made good.

That the hydrants, hose, etc., in and about the premises are kept in proper order and are not obstructed by fittings or goods. It is well to have the direction in which hydrants and valves should be turned to open marked by an arrow and the words "To open," added.

That the extinguishers and fire pails are filled and in order.

That the water supply is sufficient and the hydrant covered in time of frost, and kept clear of snow, etc.

That the fire alarm and sprinklers are in order.

Any instructions to the workpeople for their guidance in case of fire should be short, couched in clear language, definite, and in every way practicable.

Careful note should be constantly kept of any risk of fire from adjacent property, and any probability of failure in the water supply or public services.

Keep upon good terms with all, especially neighbouring fire brigades.

Every member of a private fire brigade should have a personal duty to perform besides joining in the general drills and duties, and in order to ensure the duty is always carried out a second man should be fully acquainted with the work and ready to act during holidays or illness.

Every member of the fire brigade must know the position of all fire appliances, telephones, emergency exits, gas and water cocks.

Never use the word "fire" in a command except for a fire, even at drills.

In case of fire, arrange that more than one method is used to send the call to the central position or station; use three if possible, one in writing. The time taken to write a message is short and it will help the sender to pull himself together and steady his nerves.

Stop all machinery, close all windows, and, after seeing that everybody is out, close the doors, turn off all gas, and switch off all electric current. The workpeople usually have time, if they keep cool, to take with them out of the workrooms and deposit in safety such portable articles as they may be employed upon at the time of an alarm. By so doing, valuable property may be saved from damage.

As mentioned in Chapter XV., it is no sign of incompetency to send for help, and the public brigade should always be notified at once of any fire. Should their services not be required, the credit will be to the private brigade.

Remember the duty of a fire brigade is to keep down the pecuniary loss, however caused. A portion of the brigade with helpers should undertake, even during the progress of a fire, to direct spent water into drains, cover up or remove goods that may become damaged, put out small burning matter, colloquially known to the fireman as "bulls' eyes," clear off smoke when the opening of windows will not cause a draught to the area on fire, and dry up the floors, etc. (see Chapter XV.).

PART IV.—FIRE PREVENTION AND PANIC

CHAPTER XVII.

FIRE PREVENTION AND PANIC IN PLACES OF PUBLIC RESORT.

This is perhaps one of the widest subjects that one would be called upon to deal with in fire brigade work. It involves the consideration of many complicated and difficult questions, not because of any lack in the scientific methods of combating fires, nor because of laxity in the administration of building and other laws to ensure the safety of life and property. The real difficulty is that in all places of public resort there seems an implied responsibility resting upon the authorities generally for the safety of the lives of the public whilst present and that the conditions existing must have *de facto* been considered.

This would be the ideal position, but unfortunately in practice it is not always the case. Only a small proportion of the enormous number of places where the public congregate has ever been brought to the notice of the authorities. Many places where the public resort are licensed, and therefore, are made to conform to a certain standard of safety; but against these must be set by far a greater number of places where very little supervision or control of the arrangements is possible in the existing state of the law.

To deal with the different types of cases it is convenient to save repetition to roughly classify them under two heads, viz. :—

A. Those which conform to certain regulations made under authority of an Act of Parliament for the protection of life and property from fire, and

B. Those without any control whatever—*i.e.*, in which the arrangements have not been supervised by any public authority.

Under A, are such places as theatres, music halls, cinemas, lodging houses, and some hotels and halls.

Under B, churches, pavilions, hotels, boarding-houses, halls, large retail shops, exhibitions, railways, hospitals, workhouses, schools, pleasure steam-boats, bazaars, and travelling circuses and large temporary structures erected for public ceremonials.

So far as the accommodation of the public is concerned in the two different classes of places, there is very little to choose from the point of view of numbers. Many unlicensed and uncontrolled places accommodate a larger number of the public than licensed ones.

The numbers of the public attracted to large shops, travelling shows, circuses, etc., frequently greatly exceed the audience accommodated in the largest theatre. Yet, whilst the Theatre Management has to conform to

legislation aimed at guaranteeing the safety of the public in the event of exit under emegency conditions, and also to regulations designed to minimise the risk of outbreak of Fire, these other organisations, owning buildings, often purely temporary in character and packed with combustible materials, are under no obligation to comply with any precautions, not even of the most elementary kind. In a minor degree, because generally less loaded with combustible materials, churches belong to this unprovided for class.

This state of things is anomalous and gives a false and dangerous sense of security to the trusting public.

Only when some grave disaster occurs, is the astonishing limitation of the authority of those who undoubtedly should have the matter in hand, made generally known.

The amazing fact is that the authorities themselves recognise the position and suffer impotently under the injustice of the summary judgment of the public, that duty has been neglected, when, of course, that duty has indeed never been laid upon them. Psychologically, it would seem that the public have placed such a duty on the authorities, and it would be but squaring public opinion with the real situation either to disclaim any responsibility in such cases or to bring the exceptions into the scope of the regulations purposely designed for the protection of the public when congregated together.

Not only is the present situation often most unfair to the public authorities, but it places the exceptions in a better position in the competitive market for business, as by not having to conform to standard protection, initial expense is saved.

However unfair the incidence of the law is, in dealing with the safety of the public, and notwithstanding how necessary it is in their interests, that all buildings where large numbers assemble should have efficient means of protection from fire, and the best structural arrangements for protecting life in case of panic, it is hardly the object of this present work to advocate any special legislation on the matter. Sufficient it is to say, that an anomaly exists, and that it is mainly owing to this that when fires occur in unregulated premises lives are often lost.

It is by no means, however, the first time attention has been drawn to the subject. Shaw, in 1870, attracted a good deal of notice by his reports to the Home Office and in his private writings on the condition of London theatres and other places of public entertainment. But the outcome of his work has only partially succeeded in removing the danger. Not all Shaw's advice, however, was accepted, or at any rate if accepted, adopted. He singled out theatres as the worst spot for danger, but he also mentioned other places, as schools, hospitals, and similar institutions.

Many of these places have undergone improvement in conformity with the slowly extending knowledge of hygiene and building, and have thereby incidentally removed many defects in the matter of exits and improved the safety of the public in case of fire.

It is to be hoped that the improvement which has been made in the last 30 years may be pursued and extended until it includes all buildings where persons are drawn together in great numbers, and that, by the universal adoption of protective and preventive means, the stigma at present attaching to administration by government departments and municipal authorities may be removed.

Ancient buildings.—The causes which lead to disaster and loss of life by fire in places of public resort are known to almost all firemen. But even these men will be the first to admit that some of the difficulties to be overcome to render ancient buildings safe are often of such a character as to be almost irremediable. It is not uncommon to find that the exits of historic buildings are considerably below the present level of the pavement outside, and that steps have to be ascended before the public can reach the open. Again, galleries have been inserted without alternative means of escape, and to make efficient provision for this may mean such a drastic interference with the fabric as to cause considerable criticism, with the result that nothing is done.

In such cases as these it is next to impossible to suggest remedies except to prevent, by increased vigilance, anything happening which may become the source of fire or panic.

Theatres, Music Halls.—The old style of theatre building with little or no effective fire separation between the stage and the auditorium, a common or continuous roof over both spaces, the lack of special facilities for storing disused scenery in a safe place, and the tortuous passages and winding staircases for the escape of the public, besides many other objectionable details which would be sure to contribute to, if not actually to be the cause of, disaster on the outbreak of fire, cannot be compared with the theatre and music hall of to-day for safety.

Theatres and similar places of amusement should not only be made to comply structurally with the most up to date ideas based upon the latest scientific research and experience, but the conduct thereof should also be carried out in a manner approved by the local authorities.

Site is, of course, a very important matter and has a great bearing on the ultimate design of the building. The ideal site would be an island one surrounded by broad thoroughfares, but as these conditions were not demanded in the past, many of the older places of amusement are not even adjacent to streets and abut on buildings which in themselves, by reason of their uses, are dangerous. The difficulty, therefore, in dealing with the old class of property is great, and often strong cases are made out against incurring any large expense to remedy the prime objection to licensing such buildings which adjoin others of greater fire risk. Nevertheless they must in all reason be considered as a danger to the public using the building.

The ideal is, in the majority of cases, widely departed from, and theatres and like places are approved on condition that the adjacent or overlooking division walls have no openings. But the whole question is debatable whether the expense of making the site an island one is not more justified, than the risk to life involved by a less satisfactory policy of permitting places of public amusement to remain in situations where, owing to the confined nature of the site, the provision of exit accommodation for the rapid dispersal of an audience is strictly limited.

Compromise is always a very inadequate and makeshift way of meeting an awkward difficulty, but it has frequently to be resorted to when dealing with old property. It is obviously the duty of those responsible for the safety of the public in places of public resort (be they local authorities, owners or lessees) to see that ample exits are provided for the escape of the public. For although the destruction of the building and its contents would

be a great financial loss, it is a very secondary matter compared with the loss of life. It is most essential that the primary consideration should be that of exits, without any abatement of the recognised standard set out below.

The numbers of persons to be accommodated and the means to accommodate them are perhaps the most vital things to be considered in all buildings of this kind. Almost every precaution it may be necessary to take depends upon the possible number of the audience. When the capacity of the proposed building is settled, the passages, staircases, exits, and a host of other important details can be determined.

There are several methods in computing the accommodation of a seated audience. It is usually based on the assumption that a person occupies 4½ square feet, allowing in this figure the space necessary for gangways. But it will be seen that on this basis more people could be got into a hall than could be accommodated with seats, so to overcome this, persons are usually permitted to stand in the back and side gangways so long as sufficient space is left for the easy passing of a single file of persons to and from the seating.

Two separate exits should be provided from every tier or floor and it is a very good plan for exits to be so arranged as to deliver in opposite directions and into different thoroughfares. Two such exits should never be connected in such a way that the two streams of traffic meet in the building. It would naturally cause some hesitation and congestion and possibly accidents. The speed of the audience passing out of a building varies greatly with the circumstances, being slower at steps and stairs, especially if ascending, and quicker at declines, but where inclines are followed by steps the average rate of travel is arrested, the same when awkward bends occur.

If the passage is tortuous with abrupt turnings, groups of persons are often left in corners, and where handrails are not placed there is also a tendency for the speed to be very unequal. The centre of a stream of traffic can generally move faster than the sides, and that is the underlying idea for limiting exits to 5 feet in width. The traffic would advance three abreast making one in the middle and one on each side. Should an accident happen those at the side of the stream of traffic would have the use of a handrail, and should anyone fall greater danger could be averted if the rails were grasped, whilst the middle person could as easily grasp one of the side passengers. Streams of traffic where five or six persons are abreast are to be deprecated, and sudden or awkward recesses should, if permitted, be always strongly defended by hand rails.

In most towns it has become almost a conventional habit for exits to be limited to 5 feet in width. At each level two are usually provided for the first 500 persons and one additional for every succeeding 250, although in other places such as very small halls accommodating less than 500 persons, two exits of 4 feet wide are allowed.

Of course, to make plenty of 5-foot exits and yet limit the width of the passage serving them would be equally as bad policy as limiting the exits themselves, because it would restrict the egress of persons in sufficient speed and tend to cause a congestion, probably at the seat of danger.

Crush halls or expansion spaces have become in more favour of recent years. It certainly saves the immediate discharge of a large number of persons direct to the public way, but the wisdom of this policy to a fireman may be doubtful. It only encourages congestion of the passages at the

opposite end to that formerly congested, and tends to collect persons rather than disperse them. The exits from a vestibule should at least be as ample (if not more so, having regard to the habit of people to congregate therein) as if the exit passages discharged into the public way direct.

Most theatre fires have their origin on the stage side of the building. For this reason the erection of the proscenium wall should never be passed over. Its great use in separating the two risks of the auditorium and the stage has been demonstrated over and over again since it was first instituted. It should be of solid brick material and the openings should be as few and as small as possible. In London, the openings are limited to two in number in addition to the proscenium. The thickness of the wall should be in proportion to its height, and the wall should be continued as a division wall through and above the roof to effect a proper fire separation in the roof space. The smaller openings allowed should be fitted with self-closing fire-resisting doors and should always be kept shut. The main or large proscenium opening should have a properly constructed fire screen or safety curtain fitted.

Since fire curtains were first introduced, many improvements have been made, both in design and in the material employed. Many firms have specialised in this class of work. The curtain should completely and effectively cut off every chance of flames reaching from one part of the theatre to another. It should obstruct the passage of flames in the auditorium reaching the stage and *vice versâ*. The curtain should not be unnecessarily heavy.

The modern fire curtain consists of a mild steel frame built up of angles, tees and piping. This frame is lined on both sides with asbestos cloth interwoven with wire. The intermediate space is either filled with silicate cotton (slagwool) contained in small wire netting mattresses, or occupied by a midfeather, about ¼-inch thick, of some compressed cement and asbestos compound of the "uralite" type. The total thickness of the curtain is about 4 inches. Vertical channel irons retain and guide it laterally, and it is suspended from at least three points by wire ropes leading to two cast-iron counterweights and a winch. The counterweights are guided and, generally, encased. A dash pot connected to the suspension system allows the curtain, when released, to fall fairly rapidly and then to seat itself gently in close contact with the stage. The time allowed in London is 7 seconds from the start to within 18 inches (0·46 m.) of the stage, then the brake in the form of the dash pot comes into action, the curtain being completely down in 21 seconds. A toe pad at the foot of the curtain ensures a good joint with the stage floor. In the latest modern practice, in order to counteract the pressure developed during the first few seconds of a fire on the stage and the subsequent suction of the draught caused by the opening of the vents over the stage, bolts have been fitted into the stage at the foot of curtains having wide openings.

The pressures entailed (trivial indeed, being only equivalent to a few inches of water) when acting on a large area, like a curtain, represent a very considerable force.

The effectual holding of the curtain, which tends to buckle on exposure to fire, is an important matter, and a drencher pipe is, therefore, fitted on the stage side to prevent, or rather delay, excessive expansion or weakening of the metal framework.

It is desirable to arrange release handles for lowering the curtain on either side of the proscenium opening as well as from the stage door.

The heavier type of metal-framed curtain lined with corrugated iron, although not fashionable in this country, has, when well designed, its good points.

The sheet metal curtain is considerably stronger than the asbestos and uralite design, and is not so liable to be damaged by falling woodwork and debris, and the great weight of the structure further tends towards its stability.

Other structural considerations for the safety of the public involve the prevention of fire by the elimination of all panelling, thin wood linings, partitions, barriers and other obstructions to rapid egress, and the provision of a properly ventilated brick scene store. Dressing rooms have in numbers of cases been the seat of fires and many persons have been trapped owing to the exits becoming rapidly smoke-logged and perhaps the rooms having no efficient means of ventilation. The precautions necessary to be adopted in these places, beyond having as complete and permanent fire separation as is compatible with proper structural arrangement of the premises, should not be more severe than would be taken in any other licensed building where flimsy materials and unprotected lights are often in use.

In addition to these structural and managerial precautions to prevent fire and panic in places of public entertainment there remains the provision of fire appliances, the systems of lighting, heating, and ventilation and some special constructions on which a few remarks will be added.

So far as the provision of fire appliances may be thought likely to be of real protection, they should be installed upon the most up to date lines. Water mains should be always charged and there should be no waiting for the water so necessary in case of emergency. The dry pipe arrangement requiring someone to hunt for a key should not be permitted. Frequent tests should be made to see that the water has not been turned off, as has sometimes happened. To obviate any leakage at the valves causing the hose to rot, drip cocks can be fitted to the hydrants. All equipment, key, cutting hooks, branch, etc., should be kept clean and in good order ready for instant use. The number of hydrants required will, of course, vary with the building to be protected. Opinions differ widely as to what is a sufficient number. In one particular locality a theatre accommodating not more than 600 persons had as many as 14 hydrants installed. On the face of it, this was ridiculous. It could never have occurred to the authorities requisitioning them that should a fire occur and unauthorised persons turn on a number of the hydrants there would be no water pressure, and the firemen might be in the greatest jeopardy. It is, however, noticeable that of late years saner counsels have prevailed in this case, and the theatre management have been allowed to reduce the number.

It is well to have upon the supply main a valve that can be closed during repairs, and its position clearly indicated on the wall so that in the event of any inside hydrants being damaged at a fire, it can be at once used, but great care must be taken that it is reopened before the workmen leave the premises.

To the writer it appears only reasonable that the number of internal hydrants provided should in a large measure be regulated by the outside

protection. Where the number of street hydrants available is good, the number of internal hydrants in the auditorium never should exceed two per level, unless the local conditions are exceptional.

The stage must be protected by hydrants placed in positions not likely to be obstructed by scenery, and where men are upon duty. The full sized mains and hydrants should be at all levels, but those in the flies may be fitted with adapters, reducing the outlets to 1 inch (0·03 m.) in diameter. These smaller hydrants should have couplings screwed to 1¼-inch (0·032 m.) gas thread and attached to 1¼-inch (0·032 m.) hose, with a 10-inch (0·25 m.) copper branch pipe, and a ⅜-inch (0·009 m.) nozzle.

The object in having smaller hose and jet in the flies is that in practice it is found that the men working in the flies delay opening a full-sized hydrant upon account of the damage that may be done by the water, also they will not remain at their posts if they think the outbreak has obtained such a hold that the small, easily manipulated jet will not suffice to extinguish the fire.

It is presumed that all theatres will be constructed on the latest principles with a brick or incombustible proscenium wall from the foundation to at least 3 feet (0·9 m.) above the highest part of the roof. Experience has shown that where a proper curtain is provided and is in position, a fire can be confined to the stage or auditorium if the fire appliances are expeditiously brought into play. In order to overcome any time lost by the public brigade in laying out hose up the stairs, the provision of a dry rising main from the street level to the top of the proscenium wall has been strongly advocated, the lower end of the dry main to finish about 2 or 3 feet (0·6 to 0·9 m.) above the pavement, and the upper end to terminate in a properly constructed weather-tight box upon the auditorium roof. This box to contain a short length of hose and a branch pipe attached. The lower end of this main should have a female coupling to take the male end of the public fire brigade hose, and should be fitted with a male plug that can be easily removed by the firemen. A proper run should be arranged from one of the concrete staircases to enable the firemen to reach quickly the hose box. He could then stand upon the roof on the farther side of the wall from the fire, and should be able to prevent the fire spreading in the roofs and overlapping the proscenium wall.

The regulations made by the L.C.C. for the protection of theatres, etc., from fire in London may be purchased from King & Son, 2 Great Smith Street, Westminster, S.W. 1, for a few pence.

Should a fire break out on the stage, the air confined above the level of the top of the proscenium arch becomes strongly super-heated and consequently expands. If there is no other vent it inevitably flows out into the auditorium, driving the flames with it.

The following few examples of holocausts will emphasise the danger:—

Brooklyn, N.Y., Consay's Theatre, 1876, . .	283 deaths.
Vienna, Ring Theatre, 1881, ...	450 ,,
Nice, Italy, Municipal, 1881, ...	150 ,,
Paris, Opera Comique, 1887, ...	110 ,,
Exeter, The Theatre, 1887, ...	166 ,,
Oporto Theatre, 1888, ...	240 ,,
Chicago, Iroquois, 1903, ...	580 ,,

After the Ring tragedy, Austrian Engineers and Architects carried out at their Government's expense a series of valuable experiments in a large model theatre (one-third normal size).

In the course of these experiments the astounding fact came to light that with the safety curtain lowered and the smoke vents closed, the air pressure rose to the equivalent of 5 inches of water (0·181 lb. on the square inch = 0·0126 of an atms.) within 30 seconds of starting a fire on the stage.

This strong rise of pressure which naturally would drive the flames in the direction of any outlet (for instance under or around an ill-fitting safety curtain), also explains the mysterious extinguishing of the gas in the auditorium of the Ring Theatre. It was merely a case of superior pressure, for gas is seldom under a pressure greater than the equivalent of 2 or 3 inches of water.

In order to relieve any air pressure that a fire upon the stage might cause, it is now considered absolutely necessary to provide over every stage, a vent in the form of a lantern light. The glazed sides of the light which are hinged upon the bottom edge should incline outwards at an angle, so that the natural tendency is to fall out on release.

The design of these vents, which should have an area of not less than $\frac{1}{10}$ of the stage area, calls for the display of considerable ingenuity. They must be weather, draught, rust, heat and fool proof—in short, although forgotten, neglected, and often tampered with to stop alleged draughts, they must be certain of action and ever ready to fall open when the brief but fateful moment of need arrives.

It is customary to lead release lines to the prompter's box and both sides of the stage, but the uncertainty of the human element must not be overlooked, and all contingencies provided for by inserting suitable low temperature fusible links in these retaining lines. The fusible links must be installed well out of the radius of action of automatic or other water sprinklers.

The ventilation of the auditorium is another important point. The chief ventilating shaft is now generally situated immediately in front of the proscenium wall. By this arrangement any fumes or gases coming from the stage are immediately carried harmlessly upwards and away from the audience.

Before, however, passing to deal with the next class of building referred to at the head of this chapter, it should be remembered that the fire precautions of to-day have been the result of universal experience, and that, in common with everything else, places of public entertainment and theatres more so, perhaps, than any other of this class, have developed considerably. In size, in the numbers they accommodate, in the magnificence of their design, in the vastness of the total capital invested, and in the grandeur of the spectacles presented, theatres to-day surpass anything that was existing a generation ago. Even the employees far outnumber those of the later Victorian days, while the machinery "behind the scenes" has increased both in quantity and technique. Can it be wondered at, therefore, that fire precautions have had of necessity to be strengthened to cope with the changing conditions?

The provision of automatic sprinklers of the usual type over the whole

of the stage space and a dry perforated pipe over the fire curtain actuated at will, are now part of the equipment of a modern theatre.

CINEMATOGRAPH THEATRES.

Prior to 1909, no powers existed to enable a building used for purposes of the exhibition of cinematographic pictures to be controlled in the interests of public safety. Cinema picture displays given in places already licensed for other things, as for stage plays, or music and dancing, had, of course, a certain measure of safety assured although the cinema films and apparatus were not subject to control, but entertainments were given in all manner of places, often totally unsuited to the accommodation of the public. Not only were these places deficient in proper means of escape, but the arrangements for the housing of the apparatus employed was often of such a temporary makeshift order as almost to invite disaster.

Again, owing to the freedom with which shows could be given and the absence of any proper specified standard regulations, what supervision was at times obtained often differed widely in different parts of the country.

Ultimately, after several mishaps had occurred, the Cinematograph Act, 1909 (9 Edw. 7 c. 30), was passed, and this gave powers to the County Councils and the Lord Chamberlain in premises licensed by him, to take action either by delegation of their authority to justices sitting in petty sessions, or by direct administration in the rural districts. Under the Act, power to frame regulations is conferred on the Home Secretary, and the Act is administered by the Chief Officer of Police or any *officer* appointed for the purpose *by a county council*, so that fire brigade officers require a *special* letter of appointment before they have *any authority* to enter premises for inspection.

The provisions of this Act also apply to County Boroughs and Borough Councils.

The regulations are, of course, the principal feature of the legislation. They are divided into six sections, viz.:—

General,
Fire appliances,
Enclosures,
Lanterns,
Lighting,
Licences,

and these sections comprise 17 regulations.

Regulations 1-3 are under the heading General. They are definitive, and it is worthy of note that the "travelling show" is included as a building which is deemed to mean "booth, tent, or similar structure."

The next two regulations are of a similar nature and apply to all places where there is a seated audience.

Fire Appliances are dealt with under Regulation 4. It is, however, somewhat strange, that as the regulation is really designed to prevent or suppress fires arising from cinematograph films, it should read that fire appliances adequate for the protection of the "building shall be provided," and the almost useless hand grenades mentioned as the chief portable fire extinguishers.

In the worst risk of this class—viz., the canvas tent—it is practically impossible to expect more than the minimum of appliances mentioned in the regulation to be provided, and there is the added risk of the whole fabric readily becoming ignited. Suggestions have been made at different times that such coverings should be rendered fire-resisting, but this necessity has not been looked upon as practicable.

Regulation No. 5 is in two parts, and comes under the heading of Enclosures. It concerns the position of a cinematograph apparatus in relation to the audience. Part I. applies in all cases and to all classes of buildings, and describes the construction of a portable enclosure or chamber. No details or measurements are given except that if the enclosure is in the auditorium, presumably amongst the seating, a barrier must be placed round it not less than 2 feet (0·61 m.) away. Inasmuch as it is impossible in many cases to place an enclosure outside the auditorium proper, the construction of this barrier has provided no little embarrassment to the authorities administering the regulation. Needless to say, where it is impossible to provide a barrier the regulation is ignored.

Part 2 only applies to buildings of specified classes, that is, for buildings used for permanent shows. Here the enclosure must be provided outside the auditorium, and if the building is permanent, the enclosure must, in addition, be permanent, but no suggestion is given as to whether the details of a temporary enclosure would be acceptable as a permanent enclosure. In fact it is known they would not. It is becoming quite general, for the permanent cinematograph exhibitions of pictures, to make a large room and divide the space into two—one for projection and the other for rewinding films or general repair work. The size of the chambers depends upon the numbers of the machines employed. Where a continuous show of several hours duration is given, a second projecting apparatus is often of considerable convenience. Not less than 70 square feet (6·5 m.^{2}) has been found to be the minimum size commensurate with efficiency in working.

It is as well also to remember that the position of the second or rewinding room should be convenient for the operator. As the operator usually stands at the right hand of the machine whilst working, the rewinding room should properly be on his right, and on no account should it be necessary for an operator to escape through the rewinding room. This is a feature on which special care should be bestowed, especially if the chamber is not very deep; the reason is obvious. In an emergency the operator may leave the intervening door open and so add to the danger by allowing any films lying about to be set on fire. The door in any case should be self-closing.

Regulation No. 6 concerns the lantern, projectors and films, and is now generally known and complied with. Most makers of apparatus are cognisant of the regulations and arrange accordingly in the design of their machines. The usual differences are caused by those ingenious people who attempt more than the regulations require. Sometimes it is found that a bath of carbon tetrachloride or other similar substance is used to run the film through, just prior to passing through the film gate. A better picture is supposed to be obtained by this method, but in the confined atmosphere of the enclosure, the temperature of which is invariably rather high, the use of such chemicals is to be strongly deprecated as, although reducing the fire hazard, it is positively injurious to health.

Regulations 10, 11, 12 and 13 concern lighting, electric, gas, and limelight. There is nothing calling for comment. The regulations are almost self explanatory.

The remaining regulations, *i.e.*, 14-17, refer principally to the procedure of licensing, renewal and revocation. Regulation 16 deals with a movable building, and lays it down that a plan and description of the building shall be attached to the license certified by the licensing authority. There does not appear to be so great a danger in these movable structures for the audience, provided these regulations are carried out.

Danger is to be apprehended if the tent is placed in a confined space.

These regulations have been in operation for twelve years and the result must be admitted to be very satisfactory. But as in every other department of fire work, only constant vigilance prevents serious fires. The greatest care must be taken that ample means of exit is provided clear of obstruction for the whole of the distance to the public way. With regard to old buildings, where it is proposed to convert from one user to another, often much difficulty results, but it may be taken that only buildings which can be altered to obtain a standard of safety of exits similar to new buildings, should be licensed. Certainly buildings for cinematograph entertainments should never be licensed where the entertainments are given in basements or where fire-resisting separation from other occupiers of the same building does not exist.

As organs are now much used in the large cinemas, the remarks on p. 447 apply equally to organs in places of amusement.

Construction of Operating Enclosures.—The operating enclosure to be sufficiently large for two machines, *i.e.*, not less than seventy feet square (6·5 m.^{2}), not less than eight feet (2·4 m.) in depth, and eight feet six inches (2·6 m.) in height.

The rewinding room to be provided adjacent thereto, and the entrance to the enclosure to be direct from the open or by a ventilated lobby, the enclosure not to be placed in close proximity to an exit used by the audience.

The enclosing partitions and the roof to be of solid incombustible materials not less than three inches (0·08 m.) thick, reinforced as necessary.

The doors and door frames to be fire-resisting, *e.g.*, teak or oak, not less than one and three quarter inches (0·04 m.) finished thickness, the door frames to be securely fixed and the doors arranged to lap one inch (0·03 m.) over the frames and to be self-closing.

Lighting to the enclosure to be provided by windows in an external wall or by lantern lights in the roof. Each enclosure to be permanently ventilated from the highest point by a brick flue or suitable upcast cowls. A fresh-air inlet to be provided where the lighting is by means of a lantern.

The escape door from the operating enclosure to be on the right-hand side of the machine and separate and distinct escape to be provided from the rewinding room, so that in the event of fire in the operating enclosure escape from the rewinding room should not be cut off.

Where alternative escape is not practicable the partition between the operating enclosure and the rewinding room to be glazed with clear fire resisting glass in teak sashes.

From a hygienic point of view it is desirable that the walls and ceiling of the enclosure should be plastered and distempered.

The apertures to be as small as practicable, glazed, and to be fitted with steel drop shutters capable of being released from two positions, one inside and one outside the enclosure. The drop screens to overlap the opening by two inches (0·05 m.), special attention to be given to the fixing of the shutters, and the joints to be made as smoke tight as possible.

COMMON LODGING HOUSES.

The next important class of building to be considered in this division includes those places which are dealt with by the Sanitary Authorities. Again, it will be seen how lightly the matters of protection and safety from fire are handled, and, owing to the complexity of the law, how difficult it is to raise the standard of fire protection and precautions to really first class efficiency.

To deal with these houses has not been found a very easy task as there has been some difficulty in law to define exactly what is meant by a common lodging house. There is no proper definition in the Acts of Parliament. In fact, the interpretation of the term has been left, as it is in many cases, for the Courts of Law to decide. After several cases it has become more or less settled that the definition contained in the repealed Irish Act of 1860, omitted from the earlier English Acts, was intended to define "common lodging house."

The real trouble lies in the fact that no form of words has been found, which, while including every building of the class it is desirable to regulate, at the same time excludes those buildings in which regulations would seriously trespass on the Englishman's right "that his house is his castle."

Excluding London, the Public Health Act, 1875, authorises the Local Sanitary Authority to keep registers of Common Lodging Houses and to make bye-laws to govern them. In London, similar powers are conferred under the Common Lodging Houses Acts, 1851 and 1853, which have been amended and partly repealed by subsequent Acts, viz. :—

Sanitary Laws Amendment Act, 1874,
Stat. Law Revision Acts, 1875, 1878,
Local Government Act, 1888,
Public Health Act, 1891,
Local Government Board Provision Orders Confirmation No. 12 Act, 1894,
London County Council (General Powers) Act, 1902,
" " " " " 1904,
" " " " " 1907,

London Bye-laws are made under L.C.C. (General Powers) Act, 1902.

Common lodging houses are now generally defined as places "where persons of the poorer class are received for short periods, and though strangers to each other, are allowed to inhabit one common room."

This is held not to cover charitable institutions, houses let in lodgings, or rooms occupied by members of more than one family, nor cases where accommodation is paid for at weekly rates.

From this it will be seen that it is possible by a careful arrangement of detail to avoid compliance with the law. But this is mainly the affair of other departments than the fire brigade.

So far as provision against or protection from fire is involved, powers granted under the various Acts authorise local administrative bodies to frame bye-laws which have the force of law for the good regulation of such places, and invariably a short clause deals with the means of escape in case of fire.

The bye-laws are primarily designed with the object of preventing outbreaks of epidemics. The idea seems to be that guarding against fire is only a secondary importance and generally considered as not involving much risk. Hence a perpetual difficulty is experienced in co-ordinating the aims of the Health Department with that of the Fire Brigade.

Several disastrous fires, however, have served to prove that unless the means of escape are carefully considered, common lodging houses become a serious menace to life, as much from the point of view of fire as from that of health.

Alterations necessary to provide a safe emergency exit in case of fire are often rendered difficult by the health requirements conflicting with the aims of the Fire Brigade in obtaining efficient means of escape.

In order to obtain economical working expenses, considerable floor space is required, therefore many large, well-built houses of the old family type, situated in districts that have ceased to be fashionable, have been purchased by speculators who alter them at the least possible cost, obtain a licence, and place the building in charge of a " Deputy."

The legislature allows houses, portions of which are let to tenants for periods of less than one week, to be exempt from inhabited house duty.

In order to improve the health condition of the premises " through ventilation " is often demanded. The ideal way to obtain this is to open up the partition walls between the rooms on the same level. In order to avoid expense, where a common staircase serves all floors, the wall space over the doors of the rooms is often left open, or the doors removed ; this overcomes the ventilation difficulty, but it creates an exceedingly serious danger from a fire point of view.

When a fire starts in the lower part of any premises, the heat and smoke are invariably drawn towards the staircase, which, acting as a flue, would immediately cut off the escape of the inmates of the rooms above.

Although matters such as this often concern two departments of municipal work, it requires only a conference to overcome the difficulty. Sometimes a hole cut in the floor of the rooms on the side remote from the staircase, suffices to meet the situation, but this course cannot be recommended where women are concerned or where it would interfere with the separation of the sexes.

Another method, but one which is now obsolete, was the provision of the external canvas chute, but this has proved dangerous in even experienced hands.

So far as fire protection is concerned, in districts outside large towns it does not often mean more than the provision of a few fire pails conveniently placed and *kept filled* with water.

It is very seldom that a hand pump or a hydrant is deemed necessary, although, of course, occasions do arise, in the case of large buildings, when one or other must be installed.

In some places it is usual to insist on the submission of certificates of examination of boilers and the electric light installation, but granted that the

inspecting officer considered the arrangements to be reasonably safe and well installed this might be dispensed with. There is little to be gained by harassing a deserving class of persons whose enterprise and initiative accommodate at a very low rate, the poor and needy.

The storage of inflammable materials, mineral oils, etc., under stairs, and the use of unprotected lights should receive the attention they require; but these and many other similar details will occur to the practised eye of the inspector and need not be catalogued here.

Seamen's Lodging Houses.—The conditions effecting seamen's lodging houses are not dissimilar from those of common lodging houses, except, of course, that the powers for regulating them are obtained by a different set of Acts of Parliament, viz., the Merchant Shipping (Fishing Boats) Act, 1893, and the Merchant Shipping Act, 1894, Sec. 214.

A problem arises in dealing with purely seamen's lodging houses as distinct from the more superior class of lodgings where seamen may stay indefinitely in the same manner as a tourist may stay at an hotel. The law is designed to cover only those places where seamen are accommodated in circumstances similar to those for common lodging houses. Bye-laws can be made under either one of the above named Acts. The local authorities of all the large ports of this country can make bye-laws under Sec. 214 (1) of the Merchant Shipping Acts, 1894. It is definitely stated that these bye-laws do not apply to the lodgings or boardings of seamen in any house or lodgings in which seamen are ordinarily lodged. The bye-laws do not usually contain any clauses for fire protection and the maintenance of the means of escape. As the keeper of the house must be licensed by the controlling authority, who would presumably be held more or less responsible for licensing a place deficient in proper means of escape and protection in case of fire, the authorities should wisely use their discretion in this matter before the licence is granted. As to the means of escape necessary—they depend, of course, upon the design of the building, and whether it has been specially erected for use as a lodging house, or is only an adapted building. In either case the question of through ventilation—a question ever dear to the health authorities—often perplexes the authorities striving to obtain the highest efficiency both as to health and fire escape conditions. The other details are similar to those of common lodging houses.

Houses let in lodgings although dealt with by the Local Authority seldom come within the purview of the Fire Brigade officer to deal with. It is hardly a point the writer would care to debate as to why common lodging houses should be subject to conditions from which other similar institutions are immune, but such is the practice.

HOTELS AND HALLS.

With one exception, the last completes the list of buildings mentioned under "A" as conforming to some standard of protection administered by various authorities.

The exception referred to comprises a few hotels and halls which give public plays, concerts, dances, etc., and in order to obtain the necessary licence therefor, it may be necessary to carry out such alterations for

structural safety and adopt such regulations for good management as are deemed essential by the licensing authority.

There is nothing of special note to distinguish the arrangements in these places from other licensed places of public resort except in one important particular, and that is in reference to what is commonly described as a temporary proscenium.

According to law any building which is used for the public performance of stage plays more than six times in any year must obtain a licence from the *local authority* and in this way supervision of such temporary arrangements as may be required are maintained by the licensing authority. Otherwise, that is when less than six performances are given, a licence is unnecessary, but the precautions should be in accordance with the standard of safety usually required in the case of temporarily licensed buildings. This is only the case for stage plays.

The question of the precautions essential in halls used only occasionally for purposes usually requiring important safeguards has always presented a problem of the greatest difficulty to the authorities.

The temporary proscenium and draperies, skyborders and wings—the temporary extension of the lighting systems, the installation of a means of colour or effect lighting, the lack of proper seating arrangements, the structural difficulty of the insufficiency of exits for the numbers of the public to be accommodated and the position of the stage in relation to such exits render the risks attendant upon temporary shows more imminent than in almost any other class of building.

Attempts have been made to minimise the danger by regulations permitting only a specified quantity of scenery properly treated with fire resisting substance. This has not been found altogether satisfactory as it bears so little relation to the other parts, and that while the amount of scenery allowed was a source of danger, yet the real trouble was not so much the quantity as the inflammability of the material in proximity to the other sources of danger. Again, owing to the rapidity with which at certain seasons of the year these shows are organised it is not always possible to examine minutely all the arrangements and ascertain whether any bad joints in the electric lighting exist, and that no properties involving naked flames or fire are brought into close contact with other inflammable material and that all reasonable precautions have been taken.

It is not in places where proper precautions of a permanent character have been taken, and where large numbers of the public are accommodated almost daily, that the most danger exists. Indeed, by constant use, forethought, and inspection, very little trouble arises. It is the occasional show in the local hall, the Christmas or New Year's party, or some such isolated or singular function where most accidents happen. The more temporary the arrangements the greater the risk.

As to what precautions should be taken this depends mostly upon the peculiar circumstances or conditions found existing. Generally speaking, by the application of common sense in allowing no unprotected lights to be used, by making fire resisting all inflammable fabrics, especially textiles, by battening chairs, and arranging the seating so as to afford rapid exit with as little possible congestion, and by not unduly crowding the hall, much

danger will be averted. One very important point to remember is that in all cases the platform or stage should be remote from the exits.

We will now turn to consider "B" class—the places over which the authorities have no control. These places are, as it were, a closed book to the fireman. He has no authority to interfere in anything, no matter however dangerous, and, as has been pointed out before, only disasters reveal to the world how bad some of these places are.

There is in nearly all walks of life a rooted dislike to official interference. It is noticeable at all turns, but it must appeal to common judgment that where the lives of hundreds of the public are involved no great hardship should be caused by an intelligent admonition, by a preliminary visit by the local fire authority and the adoption of simple fire precautions.

Church, Chapel.—It must not be understood that the places with the greatest hazard bear very pronounced evidence of such on their face. Often indeed they appear to be perfect specimens of up-to-date arrangements and safe. One might say there is not much risk of fire in a church or chapel. There is nothing to burn. And yet insurance companies advise that severe fires are of comparatively frequent occurrence, and that, through a mistaken idea of immunity and safety, grave risks are incurred and great damage is often the result. Lightning, for instance, is a frequent source of fire, especially to churches, etc. The number of churches that have been struck and destroyed should easily convince the most sceptical of the danger in this direction. The lighting and heating arrangements and the automatic devices for organ blowing as well as the actual organ itself all furnish sources of possible danger. Defective flues have also caused several fires.

Of all the spots that lend themselves to insidious fires in places of worship, the organ is the most dangerous, and on account of the large quantity of thin, soft wood, glue, etc., used in its construction, a fire here is sure to make such headway in a short time that any chance of saving the organ, or in fact, that part of the building, is very improbable.

In modern organs electricity is almost always used in connection with the action, blowing apparatus, etc., although in the case of the action, the voltage is small; this causes additional risk owing to the chances of short circuiting. It has also been found that, although a flexible wire attached to a portable lamp is often provided for the use of the tuner, a candle or oil lamp is preferred by him, owing to the dislocation that may be caused by dragging the flex among the pipes, and also to the fact that the candle can more easily be introduced into the more inaccessible parts.

Constant care and supervision is required to see that naked lights are not used, and as has been known to happen, left burning in the interior of the organ when the tuners have left.

When electricity for operating is used care must be exercised to see that the insulation of the various wires is not chafed.

An organ should be so situated that the possibility of a damp atmosphere acting on it is reduced to a minimum, and where artificial heat is required, it should not be created by lamps or open stoves.

Candles and other naked lights at the key-board should be used with care, and the space round the pedals should be kept clear of paper and rubbish. Vergers and cleaners should not be allowed to use the inside of the organ case as a store for brooms, old mats, hymn books and rubbish,

and this applies also to the blowing chamber. The keys should be kept by a responsible person who should inspect every week.*

So far as the danger to the public is concerned this is slight as it providentially happens in the majority of cases that fires in churches and similar buildings occur principally when they are unoccupied. The only serious menace, is that of panic started by the raising of an alarm and causing the congregation to stampede, and the exit accommodation being insufficient for the sudden rush. Happily in places of public worship activity and levity are somewhat subdued and an air of restraint and reverence may prevent injuries to a departing congregation, but nevertheless, this can in no way be made an excuse for not securing the maximum of safety, both to the building and congregation, even by having the doors arranged to open outwards. And here it might be observed how few churches and similar places have any ready means of extinguishing fire. It would be difficult in many places to discover in an emergency even a bucket of water.

Out of 32 cases of fires in churches taken at random over a period of 9 years, 11 were caused by defective heating apparatus; 11 were returned as unknown; 2 as incendiarism: 2 due to defects in the organ electric motor; 2 sparks on roof; 1 lightning; 1 gas explosion; 1 candle upset; and 1 candle left by workman. In many instances, however, owing to the total destruction of the fabric the causes have not been capable of determination, but as stated above, the heating apparatus is the principal cause. In some cases the coal was stacked close up to and even upon the boilers.

The beautiful sculptured figures on the roof of Milan Cathedral at a height of 240 feet above the street were severely damaged some time ago by a timber staging catching fire owing to a careless workman leaving a lighted brazier exposed to the fanning action of the wind.

A very serious fatal fire occurred in Hamburg on 3rd July, 1906, through the carelessness of workmen engaged on repairs in a church tower. This tower, which was chiefly constructed of wood, was about 220 feet high, and a portion was in use by the fire brigade as a watchroom and was equipped with signalling instruments and sundry fire appliances. The workmen were employed at a level below the watchroom. In broad daylight the fire broke out and was repeatedly signalled from the watchroom above to the fire brigade headquarters. For some reason, however, the brigade were bewildered by the frenzied incoherent signals and wired back time after time "where is the fire" until finally one last hesitating signal came through "big fire here in the tower." It is to be hoped that carbon monoxide did its merciful work before the flames reached the wretched men and wrapped them with the tower in utter destruction. All the men perished.

A church in North Britain had its roof severely damaged by fire. A plumber was repairing the lead work with a lamp, the heat from the lamp was transmitted through the lead and fired the timber underneath, the workman himself only just escaped.

Another fire occurred in London, the cause of which was returned as unknown, and which was popularly ascribed to the action of the Suffragettes,

* An Architect paying a visit to an English Cathedral in August, 1925, saw a ladder resting against the organ. He went up and found upon the top a lighted candle without any protection. Upon calling the Verger's attention to this, he was told that the organ tuners must have left it when they went to dinner.

whose activities were frequently noticed about this time. The fire was doubtless caused by one or more of the by-pass jets on the incandescent gas brackets being extinguished by a draught, and thus allowing the gas to escape. The gas ascended and filled the upper portion of the church. This mixture, which apparently had reached its explosive stage, gradually fell in the church until its level reached other lighted by-pass jets, when it fired and immediately the whole of the upper portion of the church was in flames.

The church at South Wingfield, near Alfreton, Derbyshire, was destroyed by fire on Saturday, 19th August, 1922, caused by heating the church with an oil stove, the heating apparatus having been placed out of order by flood.

St. Paul's Cathedral.—In England the majority of the churches, being of Gothic design, are finished with towers and spires of stone, few of the ancient wooden spires remaining. There is, however, a certain number of buildings in the classic style, having domes; the principal one of these is St. Paul's Cathedral, London, which has a dome consisting of an inner circular roof of brick, a brick cone, and an outer dome of wood, covered with lead. Some years ago the author reported in detail on the fire protection of this building, and strongly recommended that the space between the upper and middle domes should be divided into eight compartments, so that, in the event of a fire occurring in one section, the smoke could not percolate all over the immense area of the dome and render the location of the fire almost impossible until the flames could be seen from the outside. This was to be supplemented by an improved water supply with special pumps acting automatically. Fig. 70 illustrates the proposals which were carried out, with the exception that a compromise had to be effected in order to save expense and the dome was only divided into four sections. See p. 91, Chapter III., for details of the water supply.

Pavilions, Kursaals, Etc.—What is true of churches is largely true of Pavilions. Very few are provided with any means for extinguishing fire. This condition arises, as in the case of churches, with the idea that there is nothing to burn. The pavilion style of building is mostly in evidence at fashionable seaside places, as Kursaals, where concerts and entertainments are given during the summer season, and the buildings are then closed for the winter months. Fires during the presence of the public are not of frequent occurrence. When they do happen, often owing to the lack of local provision to tackle such an eventuality, the buildings are almost always doomed, especially where they are at the ends of piers. The prospect of an outbreak in these buildings with the public present fills one with real concern, as by the peculiar situation there is only one means of escape. If the wind happens to be inshore the heat, smoke, and flame would be found a positive hindrance to any attempt at rescue whilst extinction could only be realised by the collapse of the fabric into the sea.

Hotels, Halls, Hospitals, Workhouses, Schools.—The first two of these have been previously dealt with as partly under licence, but there is a far greater number not under control. The purposes for which they are used are not very dissimilar. The only difference being that the controlled buildings have some parts which are licensed by the local authority for music and dancing, or stage plays, and as such have received a tacit approval of the conditions involving the safety of the public. In every other respect

they are the same as uncontrolled. There is no difference whatsoever, and, excluding the excise licensed portions, are as free from restrictions as any other building. The precautions against fire, both structural and managemental, and the provision of means of escape, are similar in both cases and neither receive any inspection or control after the architect has dealt with them. The building may be gradually transformed or altered that in time it has quite changed the conditions of limiting an outbreak of fire as conceived by the Building Authority in passing the original plan.

Hotels vary considerably in size and importance. The small variety approximates more towards the domestic dwelling and, of course, should be dealt with on these lines. What it is proposed to deal with here is the large pile of buildings which is found in all great cities, involving many floors and hundreds of rooms. These hotels have extensive plants for cooking, lighting and heating, and for the running of lifts, and the latest appointments for the comfort of their clients.

The number of people accommodated may run into hundreds, and it must appeal to any layman that the work of fire fighting becomes much more difficult, as these places increase in height and size, to say little or nothing of the rescue work which becomes an important feature on these occasions.

If, during the erection of these buildings, the supervising building authority has done its work properly and the building remains structurally unaltered, there should be no trouble with the structure in the event of fire. Alternative means of exit from the upper floors remote from one another should enable all inmates to escape safely. The lighting, whether electric or gas, should be on a dual system to obviate accidents in the event of failure. The heating should be on the low pressure system. Probably all these are properly installed—generally they are. It is not in the likely places where the fire occurs. Instead of a second staircase the lift may be suggested as the alternative means of escape from upper floors. Here then will commence the risk. In an endeavour to save space in planning and in order to increase the earning power of the building there is every encouragement for a lift to be installed in lieu of one of the staircases. A fire occurs in the heating chamber in the basement. Rubbish or something of the kind is ignited, or perhaps a short circuit occurs through mechanical injury in the lift well—a favourite place to run wires from floor to floor, and immediately a fire is started. The flames are drawn up the lift well, which acts like a flue. Lift wells are often lined with soft wood and the progress of the flames may not be noticed until the fire has got a good hold. Then comes the next trouble. The inmates try to escape from the upper floors. One means of exit—the lift—is unworkable. The stairs must be relied upon and by the constant rushing about of excited people the flames soon travel along corridors igniting carpets and draperies and, making headway towards the next upward leap, cut off the only escape left—the only staircase.

The fireman knows only too well what follows. Excited people are seen at the upper windows. Some have perhaps not tried any other means of escape. Rumour is always rife on these occasions and they may have been told that there was no escape any other way. In the confusion which ensues, especially at night, lives may be lost.

The possibility of escape by the roof is not often considered owing possibly to the difficulty of gaining a means of descent over other property. Way-

leaves and rights and all manner of easements and rents are involved in this matter. Sometimes escape is provided partly by an external bridge or balcony to another downward escape, but this method of tortuous routes by which to reach the ground often bewilders the fugitive. External escapes and staircases are not often lighted, and are, therefore, useless at night for terror stricken people.

In support of these criticisms, the writer has had some extraordinary experiences, and rescues have been made by scaling ladders, etc., from really first-class hotels, equipped with every detail for convenience, including fire appliances.

Bazaars and Retail Stores.—When we consider the case of bazaars and retail stores we are confronted with a condition of things to which no regulations have been applied, unless they have involved the licensing of the premises for the performance of music and dancing, etc. By themselves bazaars are under no control whatever. The risk can be of any size, and although statutory regulations as regards structures must be complied with, the arrangements for safeguarding the lives of the public from the danger of fire and panic are left entirely in the hands of the promoters.

Bazaars are not very far removed from the retail store. Hardly anyone who has ever visited any of our large towns can fail to have been struck by the large buildings where crowds gather at sale times and other special occasions. One might be safe in saying that, it is the business of the management of these places to draw the public in large numbers, but one might also add that it should follow as a moral obligation that the responsibility for their safety should be imposed with penalties for lax arrangements.

Usually such buildings are of the modern type and possess up-to-date protection; but the larger the buildings the greater the complications which naturally demand the attention of qualified men skilled in their use and care.

Bazaars and retail stores vary in size from a few draped stalls in a little church hall to a specially designed temporary structure; and from the ordinary shop, all more or less on one level, to a great emporium in a huge pile of buildings every floor of which is occupied by showrooms stocked with flimsy and highly inflammable goods. One might be tempted to say that the risk is the same, differing only in degree. This is not so, since the arrangement of each store is on different lines. The goods may be different, the protection will undoubtedly be different, and then there is that very uncertain factor, the public It is one thing to remove a crowd of people safely from a store, all on the one level; but it is quite amother matter to remove a crowd of excited people from several floors, perhaps with the lower floors on fire. In New York there exist wonderfully designed shops running through a block of buildings from avenue to avenue, which, if once on fire, would be most difficult to extinguish, as owing to their length they can only be attacked from the ends and not from the top or sides. In the comparison of risk, the danger to the public is disproportionate to the greater area of a building involved, as large floors offer inducements to the people to congregate in large numbers. When the fires which have occurred are examined, it will be found that there is not more to be said against the temporary structure than against the permanent store.

The terrible loss of life at the Paris Charity Bazaar of 1897, the disastrous

fires at Battersea in 1909, and Kensington, 1912, are cases in point. On the one hand temporary buildings were burned, and 124 people burned to death, in the others the permanent buildings were destroyed and employees lost their lives. A difference might be urged in the case of employees, but in all the cases the employees were lost in a manner that might easily have been the fate of the public.

What then is the cause of all these disasters? One at least was officially expected and reported upon years before it actually occurred. The answer is that they must be ascribed to carelessness.

To be forewarned is to be forearmed, and if the originator of the Paris Charity Bazaar (see Fig. 268), in which so many lives were lost on May 4th, 1897, had for one moment realised that the inflammable "velarium" could have involved the whole building in so short a time, he would undoubtedly

Fig. 268.

have quickly eradicated the danger. The facts were that the building had been utilised as a play house without any incident indicative of the possibility of a serious loss of life should a fire occur; that there were ample exits for its audience; that there was almost an immediate access to the street; that there was a large open ground at the rear, and finally, that the premises were only a few minutes from a fire station, everything indicated the successful handling of a fire should it unhappily break out. It looked all very reassuring, yet, in spite of all, the place was utterly destroyed.

Had the situation and arrangement of the exits and their liability to cause a catastrophe by the crowding of hysterical visitors into an awkward turning, as also the lack of provision of adequate safeguards in connection with the situation and arrangement of the private cinematograph entertainment been properly considered by the promoters; and the possibilities of the "velarium" as a rapid conductor of fire all over the building, it is safe to say that all the proper precautions would have been taken. It must

be pointed out, however, that in this instance, as is often the case, many of these precautions may have been waived because the show was of a semi-private character. The result in such cases is too well known in the fire world, and no expressions of opinion on the conditions *usually found* in the shows of this character are necessary. It is a pity that private shows are not voluntarily submitted to the opinion of experts before they opened.

Then, again, if we turn to review the circumstances of the large retail stores—such stores being a feature of business expansion which has become very common of late years, it is usually some small point, quite overlooked, which has led to great disaster. The above mentioned business premises at Battersea were replete with almost all the fittings which should have saved the great store. The building was for the most part fitted with hydrants, and iron doors divided the different departments. Yet in little over an hour this great store became a scene of desolation, converted into a mass of smoking debris and twisted ironwork through the breaking of a small incandescent electric light globe, and the heated filament falling on some cotton wool.

In another case in the City, after attention had been repeatedly drawn by the authorities to the inadequacy of the means of escape for employees, a number of females were trapped and burned to death on a roof where escape by the iron ladder was cut off by a sheet of flame.

Another remarkable case occurred in America. It had been the practice in a certain factory to have frequent fire drills and the alarm of fire was given by sounding the fire bell. So frequent had these drills become that it had bred the contempt which springs from familiarity, and alas, as in the story of the boy and the wolf, when the wolf did arrive no one heeded it, and when the fire occurred the girls proceeded so leisurely to change into their outdoor garments that by the time they wanted to escape they found they had been trapped, and 60 lost their lives.

A fire occurred at about 5.30 p.m. on the 13th January, 1910, in the new portion of a large drapery premises at Kilburn, and *within half an hour* damage to the extent of £100,000 was done. The shops were closed at the time, and only 26 people were in the building, most of whom escaped by an iron fire escape ladder.

At Kensington on the 3rd of November, 1912, a fire occurred about 1.30 a.m., upon the premises of a draper. The building was of 6 and 7 floors, 120 feet (36·57 m.) by 90 feet (27·43 m.). Five of the employees were killed in this supposed to be well-equipped building.

These fires have demonstrated beyond all question that something more is wanted than the mere assurance that the building is fully equipped with a fire-fighting system, and that there is a proper division of risks in case of emergency. In the first place, the equipment is not of the least use unless it is in the hands of those who know how to use it. Secondly, to have installations for dealing with fires and bury them away behind counters and other inaccessible places is not to facilitate their rapid employment when needed, and to have effective means of dividing risks by walls and yet to allow the separating fire doors to be blocked with goods, shows that every building of large proportions, where the risk is consequently great, should have proper supervision by the employment of a fire-fighting staff.

Strict and frequent inspections are especially necessary in large buildings where every floor is piled with inflammable goods, and where the means of escape for panic-stricken inmates are often not so adequate as is desirable. Such measures would be a perpetual safeguard and insurance to the owner and public alike.

Hospitals, Workhouses, Convents, Infirmaries.—To avoid as much as possible the repetition of advice these buildings may be taken together. There is a great similarity in their uses, although one may not at first realise it. These places deserve the best treatment of any, for where sickness prevails, greater care is required to ensure that not only the most efficient means of extinction is provided, but that outbreaks are very carefully avoided. It seems strange that where such care is taken to nurse patients back to health, it is only in a few instances that the proper authority is charged with the duty of ascertaining that the safety from fire and means of escape are efficiently maintained.

From the fireman's point of view, all those affected in mind, body, or estate are in one category. Happily, a wise and charitable intelligence seems to pervade the management of these institutions, and saves the inmates from some of the risks which fires entail.

The general lay out and internal fittings of such places do not easily lend themselves to an extensive conflagration. The spacious grounds, wide areas between buildings of limited height, and surrounding balconies, all help the work of rapid exit in case of emergency. Then, again, there is that invaluable fire drill and constant attendance of the medical and nursing staff which makes the early detection of a fire almost assured.

Most large institutions are equipped with fire appliances and in their drill the staff put the appliances in action. The procedure is good, both for insuring the workable condition of the appliances and for keeping the staff in trim.

But it may be wise to sound a warning note even in these cases. Temporary buildings should not be allowed, but if absolutely necessary should be carefully guarded and placed a good distance from permanent structures. Any underground or other passages and pipe ducts should be carefully divided by fire-resisting walls.

Schools.—Here we are face to face with what ought to be a risk of comparatively little danger. And yet many fires of a serious nature have occurred.

Schools are of various kinds. There is the ordinary day school where scholars are accommodated in a spacious building, of more or less fire-resisting construction. There is the smaller village school and not so substantially constructed, this last defect being invariably compensated for by the school being only of one storey. And lastly, there is the public school where the building is more or less of ancient foundation, and where all the errors of construction contributory to fires can be found.

The latter category brings to mind a fatal fire which occurred on 1st June, 1903, at one of the school houses at Eton College. Two boys lost their lives, one being unable to get out of a window fitted with iron vertical bars $\frac{7}{8}$-inch thick, whilst the other was suffocated in bed.

There is nothing to be done in dealing with school buildings but to insist upon the best fire-resisting construction, and this applies equally to the arrangements for lighting, heating and storage. If an outbreak of fire

occurs, strict discipline should be maintained, and the scholars immediately conducted clear of the building.

An important point to remember, especially in the case of schools of two or more storeys that are a distance from the road, is that the openings in the fences or boundary walls should be of such a width as would admit of the passage of the local brigade's fire ladders.

It is often stated that children should be instructed at school about fires. That it is sometimes done is proved by the fact that at the time of the outbreak of fire in the roof over the fourth storey of S. Francis' (R.C.) School, Lower Park Road, Camberwell, in the early morning of the 1st March, 1907, the following message was found by the firemen, written on a blackboard in the class room where the fire was discovered—

"Last—a fire broke out in—building in—Street. The signal—Fire Brigade arrive. Several people—on fourth storey—ladders to try and rescue—one man—impatient—jumps and in so doing—The fire—soon put out, but—building—."

What is Panic.—Fear, the Father of Panic, arises from the apprehension of coming evil. Uncertainty of the nature and extent of danger, ignorance and darkness are three great intensifying factors.

A sudden flash, darkness or a loud report all tend to upset the delicate balance of the intellectual control of our actions, and if followed by an apparent danger, more especially if of unknown magnitude, such as the sight of fire, smoke, or choking vapour, the sound of escaping compressed gases or steam, or even a smell of burning, may give rise to intense manifestations of Fear.

The outward signs of Fear are too well known to need description. Inwardly, Fear is a fixed idea of danger fast growing in intensity until it can no longer be shaken off, and terror takes command. All reasoning flies to the winds and instinct becomes the only guide to action. Individually, there is generally organic derangement accompanied by relaxation of muscles not expressly stimulated, resulting in loss of power, and in extreme cases even the animal instinct to shriek and to flee from danger comes violently to the fore, and if there is a known way to escape there is intense activity in that direction. The most awful form of frenzy with its accompanying wild frantic rushing hither and thither occurs when there is no clearly defined outlet. To these instinctive individual impulses must be added the well known but unexplained influence of the crowd.

It is common knowledge that in excited crowds composed of the most varying elements, individuality vanishes and is replaced by a state of fusion with a marked tendency towards the lower levels of intelligence present.

Such crowds in which Man returns to his primitive savage state are extraordinarily susceptible to either good or evil, and without reasoning tend to translate into immediate action any suggestion received. Crowds once aroused to this state cannot be appealed to by reasoning, but are readily influenced by repeated assertion, especially if coupled with vivid imagery and example.

Efforts at counter suggestion are valueless if diametrically opposed to the original impression. but are often effective if collateral or tangential to it.

If a crowd is allowed to receive the uncombated impression of fear at the first example of attempted flight, panic becomes almost inevitable.

Immediately a wild stampede ensues, instinctively directed towards the way by which each individual has entered the building, although there may be many other and better avenues of escape.

Some unfortunate person faints or stumbles. Others are tripped and the obstruction quickly grows to a high-piled seething mass of struggling agonised humanity, gradually crushed to stillness by the pressure of the oncoming crowd, as, mad with blind terror, it fiercely fights its way onward in an unreasoning effort to escape by a way that is barred.

A thoughtful analysis of the foregoing will make clear the reasons for, and the extreme utility of, the three great methods incorporated in the best up-to-date practice for the "Prevention and *attenuation* of the effects of Panic."

1. Prevention.

Uncertainty and ignorance are combated by accustoming the audience to the sight of safety devices and fire-fighting appliances, and it is suggested that more might be done in this direction by intelligent propaganda. For instance, in properly arranged theatres and cinemas, simple facts might be painted on the safety curtain and on, or near the operating box, such as—

"The 'so and so' theatre (or hall) is emptied nightly in five minutes. This curtain (or box) will, unaided, hold back fire for at least 30 minutes, consequently, in the case of emergency, you have plenty of time to leave quietly without pushing. Please don't forget any of your belongings. Have you forgotten your cloak, gloves, or opera glasses?"

This placarding of emptying times would also serve to show up ill-planned buildings, and to bring them into line with those on which proper care, and perhaps large sums of money, have been expended.

It should be here noted that discipline has a marked steadying effect on the dangerous impulses normally brought into play under conditions of emergency. Consequently fire or panic drill when intelligently directed and explained is always useful, but it must not be allowed to degenerate into mere monotonous automatic routine. Reasoned appeal to individual intelligence is a first essential to success and this training should be commenced from childhood's days.

In this country, the sporting instinct of the Britisher, and his desire to see the "fun" has often saved a threatening situation, but this useful coefficient of safety cannot be regularly counted on because in some crowds there is often present a large percentage of less stable elements.

This was demonstrated on the 28th of January, 1918, when even the rumour of an air raid caused the alien inhabitants round Bethnal Green Road, London, to rush for shelter under the Bishopsgate Railway Station. The young men, many of whom had escaped military service, in their wild fear fought their way through the crowd and caused the death of 14 persons.

The influence of national characteristics on the more or less perfect "will fusion" of crowds has long been observed by great thinkers abroad. Gustave Le Bon, in his famous "Psychologie des foules," enunciates the definite psychological law:—"Le caracteres enferieurs des foules sont d'autant moins accentues que l'ame de la race est plus fort" (The stronger the soul of the race, the more noticeable are the lower instincts of crowds).

Sudden darkness caused by the breakdown of the lighting arrangements is generally provided for by having the auditorium lights in public places of entertainment on two separate circuits; but unless there are also two separate sources of supply this arrangement is far from perfect. In the best practice two completely independent current supplies are provided. The illumination of the auditorium is divided between the two supplies. Where two entirely separate electrical supplies are not obtainable, gas forms a useful reserve and is a real help to ventilation. Stage lighting is on a separate circuit from that of the auditorium, and the illumination of exits and passages are entirely independent of any other system.

Every precaution is, or should be, taken in design, erection, maintenance and storage, to foresee and prevent anything that may cause fire, the escape of vapour, explosions, smell of burning, flashes, or anything that would even tend to have a disturbing influence on the audience. It is highly desirable to accustom audiences normally to leave by all exits.

Dr. Brouardel, the well-known medical expert, examined the bodies of the victims of the Opera Comique disaster in 1887. His judgment is that death resulted from three causes, but that no one was burnt to death. Some of the persons died from fright, which fact was proved by the evidence of the sudden stoppage of the circulation of the blood in the veins and heart. Others died of suffocation by oxide of carbon, which produces anæsthesis and death by its action upon the blood. Others died of suffocation by carbonic acid gas. This gas extinguished all the oil lamps on one side of the building while they remained alight on the other. Some instances of remarkable escapes are recorded. One of the most interesting is that of Mdme. Le Cour, the wife of a member of the French Chamber, who, on seeing the first sparks, suddenly rose, and, feigning illness, whispered to her husband, "Sortons vite, je suis indisposée." Now, had she told her better half that she had seen sparks on the stage, he would no doubt have pooh-poohed it and refused to move. Believing, however, that she was seriously unwell, he moved immediately, and they both got out easily before anyone.

2. Calming an incipient panic.

The playing of the National Anthem, a few words with a touch of humour in them addressed from the stage will often stabilise things at this psychological moment when reasoned action is tottering in the balance.

In one large continental city where the Fire Brigade by its energy and exceptional skill has created a great name for itself, an ancient monumental and world famous Opera House has to be protected from a considerable fire-risk. Here, great reliance is placed on the effect of the immediate entry of firemen stationed outside the exits.

Even at a fairly advanced stage of panic, without doubt there is still much to be done by a display of composure and the tactful use of humour on the part of the staff and the stronger minded elements of the audience. Many years ago a nervous youngster received his first object lesson in panic checking in rather a novel but nevertheless useful method. The Old Lyceum was packed with worshippers of Henry Irving, and representation of "Faust" was in progress. Suddenly there was an electric failure in the footlights. The small boy jumped with nervous apprehension, exclaiming

Immediately a wild stampede ensues, instinctively directed towards the way by which each individual has entered the building, although there may be many other and better avenues of escape.

Some unfortunate person faints or stumbles. Others are tripped and the obstruction quickly grows to a high-piled seething mass of struggling agonised humanity, gradually crushed to stillness by the pressure of the oncoming crowd, as, mad with blind terror, it fiercely fights its way onward in an unreasoning effort to escape by a way that is barred.

A thoughtful analysis of the foregoing will make clear the reasons for, and the extreme utility of, the three great methods incorporated in the best up-to-date practice for the "Prevention and *attenuation* of the effects of Panic."

1. Prevention.

Uncertainty and ignorance are combated by accustoming the audience to the sight of safety devices and fire-fighting appliances, and it is suggested that more might be done in this direction by intelligent propaganda. For instance, in properly arranged theatres and cinemas, simple facts might be painted on the safety curtain and on, or near the operating box, such as—

"The 'so and so' theatre (or hall) is emptied nightly in five minutes. This curtain (or box) will, unaided, hold back fire for at least 30 minutes, consequently, in the case of emergency, you have plenty of time to leave quietly without pushing. Please don't forget any of your belongings. Have you forgotten your cloak, gloves, or opera glasses?"

This placarding of emptying times would also serve to show up ill-planned buildings, and to bring them into line with those on which proper care, and perhaps large sums of money, have been expended.

It should be here noted that discipline has a marked steadying effect on the dangerous impulses normally brought into play under conditions of emergency. Consequently fire or panic drill when intelligently directed and explained is always useful, but it must not be allowed to degenerate into mere monotonous automatic routine. Reasoned appeal to individual intelligence is a first essential to success and this training should be commenced from childhood's days.

In this country, the sporting instinct of the Britisher, and his desire to see the "fun" has often saved a threatening situation, but this useful coefficient of safety cannot be regularly counted on because in some crowds there is often present a large percentage of less stable elements.

This was demonstrated on the 28th of January, 1918, when even the rumour of an air raid caused the alien inhabitants round Bethnal Green Road, London, to rush for shelter under the Bishopsgate Railway Station. The young men, many of whom had escaped military service, in their wild fear fought their way through the crowd and caused the death of 14 persons.

The influence of national characteristics on the more or less perfect "will fusion" of crowds has long been observed by great thinkers abroad. Gustave Le Bon, in his famous "Psychologie des foules," enunciates the definite psychological law :—"Le caracteres enferieurs des foules sont d'autant moins accentues que l'ame de la race est plus fort" (The stronger the soul of the race, the more noticeable are the lower instincts of crowds).

Sudden darkness caused by the breakdown of the lighting arrangements is generally provided for by having the auditorium lights in public places of entertainment on two separate circuits; but unless there are also two separate sources of supply this arrangement is far from perfect. In the best practice two completely independent current supplies are provided. The illumination of the auditorium is divided between the two supplies. Where two entirely separate electrical supplies are not obtainable, gas forms a useful reserve and is a real help to ventilation. Stage lighting is on a separate circuit from that of the auditorium, and the illumination of exits and passages are entirely independent of any other system.

Every precaution is, or should be, taken in design, erection, maintenance and storage, to foresee and prevent anything that may cause fire, the escape of vapour, explosions, smell of burning, flashes, or anything that would even tend to have a disturbing influence on the audience. It is highly desirable to accustom audiences normally to leave by all exits.

Dr. Brouardel, the well-known medical expert, examined the bodies of the victims of the Opera Comique disaster in 1887. His judgment is that death resulted from three causes, but that no one was burnt to death. Some of the persons died from fright, which fact was proved by the evidence of the sudden stoppage of the circulation of the blood in the veins and heart. Others died of suffocation by oxide of carbon, which produces anæsthesis and death by its action upon the blood. Others died of suffocation by carbonic acid gas. This gas extinguished all the oil lamps on one side of the building while they remained alight on the other. Some instances of remarkable escapes are recorded. One of the most interesting is that of Mdme. Le Cour, the wife of a member of the French Chamber, who, on seeing the first sparks, suddenly rose, and, feigning illness, whispered to her husband, "Sortons vite, je suis indisposée." Now, had she told her better half that she had seen sparks on the stage, he would no doubt have pooh-poohed it and refused to move. Believing, however, that she was seriously unwell, he moved immediately, and they both got out easily before anyone.

2. Calming an incipient panic.

The playing of the National Anthem, a few words with a touch of humour in them addressed from the stage will often stabilise things at this psychological moment when reasoned action is tottering in the balance.

In one large continental city where the Fire Brigade by its energy and exceptional skill has created a great name for itself, an ancient monumental and world famous Opera House has to be protected from a considerable fire-risk. Here, great reliance is placed on the effect of the immediate entry of firemen stationed outside the exits.

Even at a fairly advanced stage of panic, without doubt there is still much to be done by a display of composure and the tactful use of humour on the part of the staff and the stronger minded elements of the audience. Many years ago a nervous youngster received his first object lesson in panic checking in rather a novel but nevertheless useful method. The Old Lyceum was packed with worshippers of Henry Irving, and representation of "Faust" was in progress. Suddenly there was an electric failure in the footlights. The small boy jumped with nervous apprehension, exclaiming

"Oh, what is that" but was immediately soothed by a solemn and well directed clout on the head.

3. Attenuation of the effects of Panic.

This is best effected by considering a panic-stricken crowd as a torrent which cannot be stemmed, but which can be enchanneled and directed to safety.

In concluding this review, mention must be made of some accidents and isolated instances which must undoubtedly be informing to all those whose duty leads them to the study of the vital questions which effect the safety of the public from fire and panic.

The principal avenues in which the public congregate have been dealt with in the foregoing pages, but occurrences like the General Slocum disaster in America in June, 1904, in which more than 1,000 persons lost their lives mostly through panic should not be forgotten, see p. 199, Chapter V.

Another instance to be noted is the question of fire on railways. So far as concerns ordinary railways open to the air, the danger is not really of much magnitude, as on the first signs of fire the trains can be brought to a standstill and the fire speedily dealt with. The case of underground railways is different. Confinement in a tunnel by the cutting off of the current may make all the difference in the world between safety and disaster in case of fire. Happily a wise foresight of the Board of Trade and the Railway Companies has operated in the introduction of really good safeguards against the spread of fire, and though fires do occasionally occur, we have in this country so far been saved a disaster such as that which occurred on the "Metro" in Paris on the 10th of August, 1903, at a time when traffic is usually brisk, 7.45 p.m. An empty train was being drawn by an electric locomotive when the motor set the train on fire. The electric light was extinguished by the wires being fused. A second train full of passengers tried to force the first train through the tunnel to the terminus but stuck. A third train ran into the standing carriages and the whole caught fire, the flames rapidly spread along the whole train. It was of course, most difficult to attack, and it was not until 3 a.m. of the next day that the fire was extinguished. Many of the passengers were able to walk along the line and thus escape, but 84 persons lost their lives.

All fires, especially those involving loss of life, are to be regretted, for it is the opinion of most experts that when all is said and done Carelessness is the verdict which must be given in nearly every case.

Whether by continually calling attention to the necessity of the utmost foresight and to the constant menace of disaster, a moral feeling of responsibility will be engendered when disasters occur, it remains for time to prove. Although the deficiencies and anomalies of the law have been mentioned, the law can never make people careful. But by the moral obligation of securing the safety of people congregated together, and by the willing assistance and advice of an experienced authority it would seem that little difficulty would arise in putting into operation the most efficient safeguards to life and property from the devastating action of fire and panic.

CHAPTER XVIII.

THE CONSTRUCTION OF BUILDINGS FROM A FIREMAN'S POINT OF VIEW.

It is of the utmost importance that a Fire Brigade Officer, and in fact, every Fireman who wishes to understand his work, should have a good general knowledge of the manner in which buildings are constructed.

An observant man, conversant with the construction of buildings, will, almost invariably, when looking through a building make a mental note of the way in which it is erected. He will also detect cracks and the presence of bond timber in walls and unprotected iron joists and columns.

An experienced man can often walk with safety over a partly consumed floor where another, who had failed to notice the way the joists ran, would fall through.

Timber *in situ*, even when much burned outside, will stand considerable strains, but to estimate how it has been reduced in strength or how much the walls are weakened by cracks and burnt-out bond timber, requires considerable experience.

Walls which, owing to age or the action of fire, are overhanging, require careful watching to see that they do not reach a dangerous angle. When the overhanging is due to the expansion of the inner surface through heat, the wall may often be restored to its former position by cooling the inside with a jet of water from a branch.

Most old buildings are built of brick, stone, and timber, all of which are usually found in the locality in which they are erected; and, as the cost in those days was reasonable, plenty of material was used. This is especially true in regard to timber, much of which was from the hard wood trees.

Local materials have, therefore, a great bearing upon the solidity of a building, and its resistance to the action of fire. The older buildings in the City of Paris, for instance, are protected in a great degree from serious fires by the extensive use of Gypsum (Plaster of Paris) in the construction of floors and staircases.

The desire for cheaper buildings, and the increased cost of land in towns, has led to the use of thinner walls, and fir timber in small scantlings for floors and roofs, with a consequent reduction in the fire resistance of the structures.

The need of protection from fire varies according to the purpose for which the building is used, and for this reason a mean standard is considered in most cases sufficient, so long as the structure will resist fire until such time as outside help may be available.

There is much force in the saying of a well-known French author, "Allumez une fournaise autour des pyramides d'Egypte et vous en ferez de la chaux"; and, if it be true that a strong fire could turn the pyramids

of Egypt into lime, those persons should blush who talk so glibly of what they are pleased in the present day to term euphemistically fire-proof buildings.

At the International Fire Prevention Congress in London in 1903, which was attended by most of the scientific firemen of the day, it was agreed that the term "Fire Proof" was a misnomer, and this term should not be used in any general, business, or technical vocabulary, but that the term "Fire Resisting" should be substituted.

The Congress confirmed the British Fire Prevention Committee's proposed standards of fire resistance and resolved that the universal standards of fire resistance should in future be: 1. Temporary protection; 2. Partial protection; 3. Full protection; in accordance with the following Schedule (see pages 461 to 463).

The principal materials used in the construction of "Fire-Resisting" buildings are:—

Asbestos.—This is a fibrous variety of hornblende, separable into flexible filaments of flax-like appearance and silky lustre, and is practically incombustible. Its low thermal conductivity, even when incandescent, will prevent the passage of high temperatures. It is much used for packing glands and pistons, for filling in the framework of fire-resisting curtains in theatres, for lining safes and doors that may be subject to fire; when used for covering large openings, such as that of a theatre proscenium, the material can be considerably strengthened by having thin brass wire worked in with the asbestos fibre during the process of weaving. It is also useful as baffle-plates to protect wood work from radiated heat. By incorporating asbestos in plaster work the fire-resistance of the latter is greatly increased. Asbestos, when mixed with a mineral glue and a small quantity of chalk, can be compressed into sheets for use on partitions and doors, and as a covering for roofs in the form of slates. Uralite owes its fire-resisting qualities to the asbestos it contains.

Bricks, when well burnt, are undoubtedly the best of all materials for resisting fire, but bricks are of many kinds, and their fire-resisting qualities largely depend upon the nature of the clay from which they are made, and the amount of firing they will stand before being overburned, twisted out of shape, or fused togther. The compactness and toughness of burnt bricks is greatly increased by the amount of iron, lime and manganese present in them, whilst the fire-resisting properties of clay vary according to the proportions of silica and alumina. The colour of bricks is mainly determined by the chemical constitution of the clay and the value of the metallic oxides it contains, but the degree of burning also exercises great effect in determining the colour. From a fire-resistance point of view, good, hard-burnt, common or stock bricks are sufficient for ordinary temperatures, but if the position is such as to be continually exposed to heat, bricks made of fire-clay containing a large proportion of silica should be used and set in fire-clay. Bricks used for giving a superior appearance and for ornamental work, such as facing bricks and rubbers, not having been exposed to so high a temperature as ordinary bricks, cannot be relied upon to withstand an intense heat. Perforated bricks soon lose their outside facing.

Concrete should be a mixture of cement and an aggregate composed of a hard material. In order to ascertain the value of various mixtures from

STANDARD TABLE FOR FIRE-RESISTING FLOORS AND CEILINGS.

CLASSIFICATION.	Sub-Class.	Duration of Test at Least.	Minimum Temperature.	Load per Superficial Foot Distributed. per square metre.	Superficial Area under Test.	Minimum Time for Application of Water under Pressure.
Temporary Protection,	Class A	45 mins.	1500° F. (815·5° C.)	Optional.	100 sq. ft. (9·290 *sq. m.*)	2 mins.
	Class B	60 mins.	1500° F. (815·5° C.)	Optional.	200 sq. ft. (18·580 *sq. m.*)	2 mins.
Partial Protection,	Class A	90 mins.	1800° F. (982·2° C.)	112 lbs. (546·852 *kg.*)	100 sq. ft. (9·290 *sq. m.*)	2 mins.
	Class B	120 mins.	1800° F. (982·2° C.)	168 lbs. (820·278 *kg.*)	200 sq. ft. (18·580 *sq. m.*)	2 mins.
Full Protection,	Class A	150 mins.	1800° F. (982·2° C.)	224 lbs. (1093·706 *kg.*)	100 sq. ft. (9·290 *sq. m.*)	2 mins.
	Class B	240 mins.	1800° F. (982·2° C.)	280 lbs. (1367·130 *kg.*)	200 sq. ft. (18·580 *sq. m.*)	5 mins.

Standard Table for Fire-Resisting Partitions.

Classification.	Sub-Class.	Duration of Test at Least.	Minimum Temperature.	Thickness of Material	Minimum Superficial Area under Test.	Minimum Time for Application of Water under Pressure.
Temporary Protection,	Class A	45 mins.	1500° F. (815·5° C.)	2 ins. and under (·051 *m.*)	80 sq. ft. (7·432 *sq. m.*)	2 mins.
	Class B	60 mins.	1500° F. (815·5° C.)	Optional.	80 sq. ft. (7·432 *sq. m.*)	2 mins.
Partial Protection,	Class A	90 mins.	1800° F. (982·2° C.)	2½ ins. and under (·063 *m.*)	80 sq. ft. (7·432 *sq. m.*)	2 mins.
	Class B	120 mins.	1800° F. (982·2° C.)	Optional.	80 sq. ft. (7·432 *sq. m.*)	2 mins.
Full Protection,	Class A	150 mins.	1800° F. (982·2° C.)	2½ ins. and under (·063 *m.*)	80 sq. ft. (7·432 *sq. m.*)	2 mins.
	Class B	240 mins.	1800° F. (982·2° C.)	Optional.	80 sq. ft. (7·432 sq. *m.*)	5 mins.

STANDARD TABLE FOR FIRE-RESISTING SINGLE DOORS, WITH OR WITHOUT FRAMES.

CLASSIFICATION.	Sub-Class.	Duration of Test at Least.	Minimum Temperature	Thickness of Material.	Minimum Superficial Area under Test.	Minimum Time for Application of Water under Pressure.
Temporary Protection,	Class A	45 mins.	1500° F. (815·5° C.)	2 ins. and under (·051 *m.*)	20 sq. ft. (1·858 *sq. m.*)	2 mins.
	Class B	60 mins.	1500° F. (815·5° C.)	Optional.	20 sq. ft. (1·858 *sq. m.*)	2 mins.
Partial Protection,	Class A	90 mins.	1800° F. (982·2° C.)	2½ ins. and under (·063 *m.*)	20 sq. ft. (1·858 *sq. m.*)	2 mins.
	Class B	120 mins.	1800° F. (982·2° C.)	Optional.	20 sq. ft. (1·858 *sq. m.*)	2 mins.
Full Protection.	Class A	150 mins.	1800° F. (982·2° C.)	½ in. and under (·018 *m.*)	25 sq. ft. (2·322 *sq. m.*)	2 mins.
	Class B	240 mins.	1800° F. (982·2° C.)	Optional.	25 sq. ft. (2·322 *sq. m.*)	5 mins.

a fire-resisting point of view, a large number of tests were undertaken by the British Fire Prevention Committee at their testing station during the years 1917-1921, when aggregates from all parts of Great Britain were obtained and tested with and without iron re-inforcement. The results of these tests are set out in a series of 31 volumes of Red Books published by H.M. Stationery Office. It is obvious that even a brief summary could not be attempted in this work, but it may be mentioned that good clean broken brick is the best, and flint the worst material to use as an aggregate for concrete that may come under the influence of fire.

Included in the 31 Red Books are the results of tests to ascertain the conductivity of heat through slabs of various aggregates, the mechanical tests, and a Geological description of the various aggregates.

Expanded Metal is usually formed out of sheets of mild rolled steel. The sheets are cut for various sizes of mesh, and drawn out so as to expand to about twelve times the original length of the sheet. It can be obtained in various strengths up to a quarter of an inch (0·006 m.) in thickness. Partitions constructed of iron framework covered with expanded metal and then coated with good plaster or cement will stand a severe fire. All iron columns and girders that would be exposed to a fire in a building should be covered with expanded metal well protected with a 2-inch (0·05 m.) coat of plaster. It is advisable to have the plaster close to the column, as if a space is left, some portion of the lathing may be damaged by falling goods and tear off, and even a small hole will allow the heat to penetrate the covering and attack the back of the steel supports.

Glass.—Fire-resisting glass is made in several different ways, one of the best being the well-known "Luxfer" Prism glazing in electro-copper frames. The glass is made in small squares and has a decorative and pleasing effect, so that smoke screens in hotels and retail stores can be made to look quite ornamental. Many large retail shops have the inside partitions of the show windows glazed with this fire resisting glass, in order to confine a fire, should such a mishap occur, as took place at Clapham Junction in December, 1909. Glazing of this type will resist for 90 minutes a fire at temperatures exceeding 1500° F. (815° C.). See B.F.P.C. 19 Red Books upon tests. Glass will not remain effective when the temperature is nearing the melting point, which may be 2000° F. (1093° C.), but is frequently much less.

Wired Glass.—Careful inspection of wired glazing, like all other matters, is necessary with a view to eliminating broken panes, especially in skylights, as experience shows that moisture frequently sinks into cracks, causing the wire re-inforcement to rust, and eventually to decay to such an extent as to be unable to sustain the weight of the broken portions, with the result that they have fallen out and caused injury to those below.

Granite.—Under this name are included rocks the constituent parts of which are concretions of felspar, quartz and mica, intimately joined together, but without any basis or ground. These parts are variable in quantity and differ in their magnitude. Coarse-grained granites are the more readily damaged by fire, and this is no doubt due to the unequal expansion of the several minerals forming the mass.

Iron, Cast (for Fusing Point see Appendix), is, generally to-day only used for columns, gutterings, light castings, such as railings, and ornamental

fittings. Unprotected cast-iron columns carrying heavy loads have been known to pass through a moderate fire of about 1,300° F. (704° C.) and still to remain usable. Cast-iron columns are subject to the disadvantage caused by the possibility of the core, during casting, being out of the centre, and therefore the metal not being of uniform thickness. It is also liable on the sudden application of water after heating to crack and split.

Iron, Wrought and Steel, is most unreliable if not properly protected.

Mortars and Plasters, to be of any use as fire resistants, require very careful attention. Mortar made from any of the fat limes and marly sand is useless. Blue lias lime and Portland cement with clean gritty sand will stand fire for some time, if of sufficient thickness. Some of the mortars used in brickwork have after many years resisted fire so well that the jointing mortar has remained in position even after the face of the bricks has been destroyed.

It is important in all cases of plastering that a good key should be formed, and in order to attain a hold for the plaster sufficient space must be allowed in and behind the lathing to hold the face in position. The author on one occasion when tracing the cause and course of a fire, found that the whole of the lathing and timber had been burned out of a partition by a fire passing from a floor to the roof, while the lime plaster on each side of the partition remained *in situ*, and apparently untouched. When plaster is used in connection with metal lathing, expanded metal, or wire netting, for the protection of structural ironwork or suspended ceilings, it is most important that the plaster should be well pressed through the mesh to form a good key upon the reverse side, and when used for casing columns and girders, that the whole space between the lathing and the columns should be filled. It has been found after fires that any space or indifferent keying in the plaster allows the face to fall away and the heat to attack the iron at the back. At the best, plaster partitions can only be looked upon as a partial protection.

Plaster of Paris is calcined gypsum (sulphate of lime), and as a building material has been used in England and France for centuries. Owing to its low thermal conductivity, it is not unusual after a fire in an old house to find that floors and ceilings constructed of reeds that had been well imbedded in plaster and laid upon the timbers, had withstood a fire below, but the reeds being consumed, the floor had to be renewed. In France, plaster of Paris is much used in construction, and the preservation of the older buildings in Paris from the ravages of fire is held to be due to the extensive employment of this material.

Non-Flammable Wood.—Several manufacturers now produce what they choose to call fire-proof wood. To render wood fire-retardent is not difficult. The treatment consists in placing the wood in iron cylinders and extracting the sap and dissolved gums by creating a partial vacuum, and then injecting under pressure into the cells of the wood "antipyrenes." The best chemicals to employ are ammonium phosphate, ammonium chloride, ammonium sulphate, zinc chloride, zinc sulphate, magnesium chloride, calcium chloride, boracic acid, borax, and alum. Unless great care is taken during each stage of the treatment, the cells of the timber will be damaged, and the wood will become brittle and will not hold nails and screws for any length of time. The weight of the timber is also considerably increased, and another

defect is the tendency for it to become hygroscopic in any damp situation, and to rust the iron fastenings.

Impregnated wood can be tested by placing strips $1\frac{1}{2}$ inches (0·04 m.) by $\frac{3}{4}$ inch (0·02 m.) and 12 inches (0·3 m.) long, over a Bunsen burner for two minutes, and noting the duration of the flame after removal. Well treated wood should show a result 20 times less than the same timber untreated.

Details of tests of impregnated wood are given in the British Fire Prevention Committee's Red Book No. 36, and others.

Paints.—Fire-retarding (but not fire-proof) paints are sold under a number of trade names, many manufacturers claiming fire-proof qualities for their goods.

Wood, coated with one of these paints will withstand the heat and flame of a match, but a few minutes' exposure to the flame of a spirit lamp will often destroy the covering; if a lamp be applied for a period of two minutes, the wood so tested should not flame or glow after the removal of the lamp.

These paints are made under secret formulæ, and for the most part are composed of sodium salts, gypsum, and silicates; these form a mineral coating which is held in position by a binder such as glue. The short fibres of asbestos are in some cases mixed with other substances and used as paint.

Frequent renewals are necessary.

Limewash or Cement Wash is a good fire-retarding solution.

Slag Wool is, as its name implies, made from slag obtained from iron ore. In order to reduce the iron ore as quarried, it is necessary to mix it with limestone which acts as a flux. When the pig iron is run off from the furnace, the residue or slag consists partly of silica, the impurities from the ironstone, and a certain amount of iron. The hard, or rock, portion of the slag is much used now for roadmaking. By injecting steam into the molten mass of the slag as it leaves the blast furnace, a fibrous material of the nature of spun glass is formed, which is full of a number of small cells. This material (also called silicate cotton through its resemblance to cotton wool) is of such a metallic nature that it is most useful for pugging floors and filling in between the studs of partitions, and theatre curtains. It is also used as an insulating material in ships and cold storage chambers. The air cells enclosed in the mass act as non-conductors of sound and heat, but only for so long as the material remains in its spongy state. If much shaken, it will fall to the bottom of the partitions in the form of a sand or powder, and thus lose one of its principal characteristics.

Having passed through the furnace it is naturally a first class fire-resisting material, and is clean and vermin proof.

Stone.—Stone, being a bad conductor of heat, is generally considered unsuitable and unreliable for use in a building that may be subject to the action of fire. On account of its low conductivity the face of any stone which has been exposed to a very high temperature, if suddenly cooled, will scale off and permanently damage the wall.

For instance, "At a fire which took place in the basement of a private house, a cupboard and some small articles of furniture were burned, and the fire was confined to the spot in which it originated. The stairs leading from the basement to the ground floor were of stone, and were separated from the basement by a door and partition both of wood, only half an inch

(0·013 m.) thick in the panels, and this door and partition, though very much charred on the inside and blistered by the heat on the outside, were not burned through. No fire whatever reached the stone stairs, and nothing but heat from above or below; no water was thrown on them to cool them suddenly, and no draught of cold air from outside passed over them, and yet they were broken into fragments and totally destroyed up as far as the first floor landing, where they ended and the wooden stairs commenced." (*Shaw.*)

Sandstone, if fine-grained, theoretically should be the best to withstand fire, but it has been found that many varieties crack and fly and soon disintegrate, and are useless for stairs and landings under fire conditions.

Limestone and Marble (crystallised carbonate of lime) are most unreliable as at a temperature of above 1,100° to 1,450° F. (593° to 788° C.), they calcine and become converted into quicklime, and thus lose all cohesion.

Terra-Cotta is made by mixing various clays and burning in kilns to a temperature of from 2,000° to 2,500° F. (1,093° to 1,371° C.). There are three qualities, known as dense, porous, and semi-porous. The porous variety is made by the addition of saw-dust to the clay; the semi-porous by the addition to the pure clay of clean calcined fire-clay, and bituminous coal, both coarsely ground and well incorporated in a mixture before firing. Dense or hard burned terra cotta is made of the natural clay with, in some cases, a slight addition of sand or crushed brick to prevent shrinkage. From the records of fires in buildings in which terra cotta was used, it appears that the dense or pure clay blocks did not stand the fire owing to expansion, while the porous variety, when under test, as also in actual fires, showed much more satisfactory fire-resisting qualities.

In the use of Terra Cotta for the fire protection of columns and exposed girders it is necessary that the porous variety only should be used, and this should be sufficiently thick, at least 2 inches (0·05 m.); all the blocks should be properly bonded and secured to the ironwork they protect, or will fail when a strong fire occurs.

Uralite (see Asbestos) is a substance made by mixing a small quantity of chalk with asbestos fibre, and incorporating the whole with gelatinous silica. It is then rolled into sheets of the required thickness and hardness. When required for roofing, a special hard type is used. It has the advantage of being as easily worked as wood, by sawing or cutting, and can be secured by screws or nails. It is, however, brittle, and is liable to crack and split when it is struck except when properly backed. On account of the non-conductivity of this class of material, and the ease with which it is fixed, it is much used as a covering for doors which may be subject to heat, and also as a substitute for lath and plaster in partitions. Asbestos slates are much appreciated in tropical countries, as a substitute for corrugated sheet iron by reason of their heat conducting properties being less.

Wood.—Timber in large scantlings, particularly the oaks and other hard woods of the non-resinous kinds, soon char, but the charcoal formed on the outside protects the core, and so long as the charcoal remains in position it prevents the oxygen in the air assisting the combustion. Partly consumed timber will remain in position and carry considerable weight.

Tabulated results of tests of the action of fire upon Floors, Doors,

Shutters, and Partitions, are given in the Journals VI., VII., and IX. of the British Fire Prevention Committee.

In December, 1918, tests were made in London to obtain information as to the relative fire-resistance and strength of certain foreign and English hardwoods, and the opportunity was taken to include ordinary yellow deal under the same test.

All samples were 24 inches (0·61 m.) long by 1½ inches (0·038 m.) by 1½ inches (0·038 m.) thick, planed on all four sides and as clean and free from shakes as the character of the timber permitted, and all the samples had been stored in the same temperature for a considerable period.

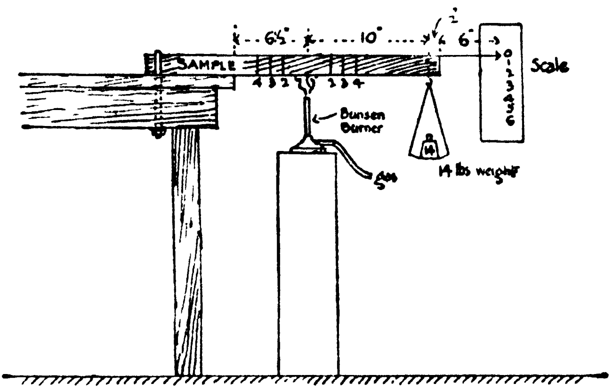


Fig. 269.—General arrangement for Wood Testing.

Method of Testing.—The sample was supported at one end and a Bunsen flame applied 6½ inches (0·17 m.) from the edge of the support and 10 inches (0·25 m.) from the point of attachment of a 14 lbs. (6·4 kg.) weight at the free end (see Fig. 269).

Number and Name of Wood.	Charring of Sample up to 2-in. (0·05 m.) mark in Secs.	Deflection just before Collapse.	Weight of Samples. Before Test.	Weight of Samples. After Test.	Time from Start to Collapse.	REMARKS.
	Secs.	Ins.	Ozs.	Ozs.	Mins. and Secs.	
No. 1. Mai Yang.	55	3 (0·08 m.)	21¼ (0·6 kg.)	19 (0·54 kg.)	22-45	The flame did not reach the 3-inch (0·08 m.) mark. A resinous substance was found to be oozing from the sample in close proximity to the centre of heat, the heat also forcing along the grain to the ends of the sample. The substance was applied to the flame and readily ignited. The sample burned with a fair amount of flame.
No. 2. Mai Takien.	87	6 (0·15 m.)	28 (0·79 kg.)	25 (0·7 kg.)	42-15	The flame did not reach the 3-inch (0·08 m.) mark. This sample did not burn so readily as No. 1, in fact there was very little flame, the effect of the Bunsen being of a more smouldering nature with little smoke. No resinous substance.
No .3. Mai Tabec.	110	5 (0·13 m.)	26½ (0·75 kg.)	23½ (0·67 kg.)	38-36	The flame reached the 3-inch (0·08 m.) mark. The sample burnt rather more readily than No. 2, and emitted a number of small sparks during the first twenty minutes of the test. No resinous substance.
No. 4. Bilian.	85	$1\frac{3}{16}$ (0·03 m.)	36¼ (1 kg.)	32¼ (0·92 kg.)		Burnt with very little flame and at the expiration of 15 mins. there was no flame whatever, the surface being charred by the heat from the Bunsen. The charring encroached but very little on the top surface, the sample proving to be of a very tough nature, in fact, so much so that after the application of heat for one hour it only showed a deflection of $1\frac{3}{16}$ inches (0·03 m.) During this test the Bunsen flame lighted back on a number of occasions, the total period being 2 mins. 5 secs.

Number and Name of Wood.	Charring of Sample up to 2-in. (0·05 m.) mark in Secs.	Deflection just before Collapse.	Weight of Samples. Before Test.	Weight of Samples. After Test.	Time from Start to Collapse	REMARKS.
	Secs.	Ins.	Ozs.	Ozs.	Mins and Secs.	
No. 5. Selangan Batu.	70	5 (0·13 m.)	30 (0·85 kg.)	27 (0·76 kg.)	40·19	The sample burnt with a little flame at first, but gradually died down to a smouldering effect. The charring encroached but very little on the top surface, the sample proving to be of a fairly tough nature.
No. 6. Moulmein Teak.	95	4 (0·1 m.)	23 (0·65 kg.)	20½ (0·58 kg.)	32·54	The flame reached the 2¼-inch (0·06 m.) mark in 2 mins. The sample burnt with a good deal of flame for the first 5 mins. A non-flammable substance oozed from the sample after the heat had been applied for about 2½ mins.
No. 7. Mahoborn Teak.	75 to 2¾ ins.	3 (0·08 m.)	22 (0·62 kg.)	20 (0·57 kg.)	35 6	The sample burnt with very little flame at first and gradually died down to a smouldering effect. The charring encroached but very little on the top surface.
No. 8. English Oak.	50	7 (0·18 m.)	24 (0·68 kg.)	21 (0·59 kg.)	40·22	The sample burnt with very little flame and at the end of 14 mins. was being charred by the Bunsen. The charring encroached but very little on the top surface. During the test the sample warped somewhat to the left.
No. 9. American Oak.	71	7 (0·18 m.)	24¾ (0·7 kg.)	22 (0·62 kg.)	28·54	The sample burnt with a fair amount of flame during the first 3 mins. but gradually died down to a smouldering effect in 6 mins. Charring encroached but very little on top surface.
No. 10. Australian Jarrah.	180	3 (0·08 m.)	26½ (0·75 kg.)	..	29·42	Charring did not reach the 3-inch (0·08 m.) mark. The sample burnt with practically no flame, the application of the Bunsen and charring encroached very little on top surface.

Number and Name of Wood.	Charring of Sample up to 2-in. (0·05 m.) mark in Secs.	Deflection just before Collapse.	Weight of Samples.		Time from Start to Collapse.	Remarks.
			Before Test.	After Test.		
	Secs.	Ins.	Ozs.	Ozs.	Mins and Secs.	
No. 11. Yellow Deal.	52	2 (0·05 m.)	18¼ (0·52 kg.)	16¼ (0·46 kg.)	27·40	Flames extended to the 2½-inch (0·06 m.) mark in 2 mins. and the 3-inch (0·08 m.) in 3 mins. 45 secs. The sample burnt very rapidly at first, but gradually died down to a smouldering effect. The heat caused a good deal of charring on the sides of the sample. No resinous substance.
No. 12. Yellow Deal.	60 to 3 ins.	2 (0·05 m.)	19 (0·54 kg.)	17 (0·48 kg)	22·3	Charring extended to 3¾ inches (0·1 m.) in 80 secs. The samples burnt with a good deal of flame and encroached on top surface to within ½ inch (0·03 m.) at the centre. At the end of 4 mins. the flames and charring did not extend beyond 2½ inches (0·06 m.); whilst the test was in progress the sample gave a slight warp to the right.

Tne conductivity of materials has had some careful attention during the past few years. The engineering department at the University College, London, made investigations in connection with fuel research, and the results were published in Bulletin No. 2 on the transmission of heat through heavy building materials. The over-all coefficient of transmission in B.Th.U. per square foot per degree F. difference per hour was as follows :—

Thickness.	Plain unplastered brick wall.	Plain unplastered brick covered with ⅝ of an inch matchboarding.
4½-inch (0·11 m.)	0·57	0·30
9 ,, (0·23 m.)	0·43	0·25
14 ,, (0·36 m.)	0·34	0·22
18 ,, (0·46 m.)	0·29	0·20
21 ,, (0·53 m.)	0·26	0 18
24 ,, (0·61 m.)	0·24	0·17
30 ,, (0·76 m.)	0·20	0·15
36 ,, (0·91 m.)	0·17	0·14

and the Bureau of Buildings of New York City, subjected different materials to a test of two hours, on a cast-iron plate, with the following result:

Material.	Temperature on face of protective material. Degrees.	Temperature of plate at back of protective material.			Per cent. above lowest.*
		Before heating.	After heating. 2 hours.	Heat trans-mission.	
Terra-cotta, dense, hollow. 2 inches (0·05 m.) thick.	1,700° F. 927° C.	75° F. 24° C.	223° F. 106° C.	148° F. 64° C.	64·4
Terra-cotta semi-porous, solid. 2 inches (0·05 m.) thick.	1,700° F. 927° C.	73° F. 23° C.	244° F. 107° C.	171° F. 77° C.	90
Plaster of Paris and shavings. 2 inches (0·05 m.) thick.	1,700° F. 927° C.	69° F. 21° C.	159° F. 70° C.	90° F. 32° C.	..
Plaster of Paris and asbestos. 2 inches (0·05 m.) thick.	1,700° F. 927° C.	70° F. 21° C.	163° F. 73° C.	93° F. 34° C.	3·3
Plaster of Paris and wood fibres and infusorial earth. 2 inches (0·05 m.) thick.	1,700° F. 927° C.	72° F. 22° C.	167° F. 75° C.	95° F. 35° C.	5·5
Concrete of ground cinders. $1\frac{3}{16}$ inches (0·03 m.) thick.	1,700° F. 927° C.	73° F. 23° C	363° F. 184° C.	290° F. 143° C.	122·2
Cinder concrete, on metal lath. 2 inches (0·05 m.) thick.	17,00° F. 927° C.	66° F. 19° C.	248° F. 120° C.	182° F. 83° C.	102·2
Metal lath and patent plaster. ½ inch (0·01 m.) thick over 1 inch (0·03 m.) air-space.	1,700° C. . 927° C.	76° F. 24° C.	296° F. 147° C.	220° F. 104° C.	144·4

The British Fire Prevention Committee's Red Books Nos. 251 and 252 give the result of a large number of conductivity tests made in cement concrete slabs of various aggregates, sand and Portland cement. Dr. C. H. Lees, who conducted the tests, deduces that for a slab the lower surface of which has been exposed to fire for a period of 2 to 4 hours the following deductions can be made.

From the temperature of the flames in contact with the surface deduct 400° F. (204° C.) for ½ inch (0·013 m.) within the slab from the surface next the fire.

600° F. (316° C.) for 1 inch (0·03 m.) " " " "

1,000° F. (538° C.) for 2 inches (0·05 m.) " " " "

* This percentage shows that Terra-cotta has about twice the conductivity of Plaster of Paris, and Cinder Concrete three times, and they are, therefore, inversely useful as fire retardants.

In nearly every case of failure of a reinforced concrete slab with only ½-inch (0·013 m.) cover to the lower layer of reinforcing rods, it was found that the temperature of that layer had attained 1,200° F. (649° C.), at which the tensile strength of the steel is reduced to 16,000 lbs. per square inch the working load, and the failure is explained by this fact.

There was, however, a number of reinforced slabs with one inch cover to the lower layer of rods in which failure occurred before that layer had attained 1,200° F. (649° C.). The observations available appear to indicate that failure in these cases was due to spalling of the heated surface of the slab or to the development of cracks in the concrete which allowed the reinforcing rods to be heated by the flames at one or more points to 1,200° F. (649° C.) or more.

The practical application of the above may explain why fires occur in buildings where actual flame has not penetrated a thin concrete floor or partition, and yet materials of an inflammable character have burst into flame, thus causing a spread of fire from compartment to compartment. The thinner forms of floors and partitions of certain concrete aggregates conduct heat well enough to raise the temperature on the side not exposed to the fire sufficiently to ignite some combustible materials. By a proper choice of the thickness of the floor or partition and the aggregate used, such extensions of the fire might be prevented or at least delayed.

Dormer window sides, skylights, and any place where flying brands might be blown from fires in the neighbourhood, should be of fire-resisting construction.

All roof-spaces should be provided with means of access, and if the space is to be used for storage it is very necessary to arrange for ample day-light, and thus dispense with the necessity of using artificial light.

Several serious fires have been experienced by the inability of the firemen to gain access to roof spaces; one in a large public building allowed a fire from a flue to burn the whole roof. In this case expanded metal had been extensively used, and it was found difficult to cut away the ceilings.

Staircases as a means of exit in case of fire should, with the exception of the entrance at top and bottom, be isolated from the interior of the building, as in all new theatres, and at the same time well ventilated. The stairways and fire escapes in buildings in which a number of persons are living or employed demand the most careful consideration of the architect as to their position, size and isolation from openings, rooms or spaces that may hold a fire. The fire need not be a large one, in fact, an oil stove or lamp left to burn out will emit sufficient smoke to prevent a person endeavouring to escape.

In populous towns the danger from neighbouring fires is usually as great as from the interior of the building served by the staircase.

Those unfamiliar with fires occurring in buildings do not understand how soon staircases and exits are obscured by smoke. Even outside iron stairs are often rendered impassable by heat and smoke from adjacent windows and openings in buildings on fire. In erecting outside staircases to old buildings it is of the utmost importance that they should not pass close to, or across, openings from which heated gases might at any time be emitted unless such window openings have been reglazed with fire-resisting glass.

It should never be necessary in new buildings to require outside iron staircases, as they should be so planned that a second means of exit is provided from each part of the building. The corridors, in which there should be no cul-de-sacs, should be divided into smoke-free sections by glazed partitions. These partitions should be constructed of teak or other hard wood, and filled in with fire-resisting glass as the latter would resist a fire of considerable intensity for some time.

Elevators and Hoists for goods, if placed near staircases should be so arranged that they can be effectually separated from each other.

Tower staircases provide the best chance of obtaining the maximum amount of safety.

Wooden stairs should always have the soffits well plastered, and all spaces next the walls well filled in.

Space will not allow details of the construction of stairs to be given, but it may be mentioned that strong timber, hardwood preferred, and good concrete carried by protected ironwork stand well. Upon no account should stone be used for "hanging steps" in which only one end is supported in a wall (see p. 466).

Cradling, Snow Boards, and Snow Guards.—These necessary fittings to prevent gutters from becoming blocked with snow, are made of wood and are often hidden in well courts and light areas. Being out of sight and neglected, they are readily fired by burning material blown from a building on fire in the neighbourhood. They should be kept under observation, and rubbish should not be allowed to accumulate under and about the laths.

Flues and Fireplaces must be properly constructed. In chimneys and flues which require soot doors, such doors must be not less than 40 square inches (0·026 m.^{2}) in size, and at least 15 inches (0·38 m.) distant from any woodwork. Flues are not to be inclined at an angle of less than 45° to the horizon, and every angle must be properly rounded, to prevent any lodgment of soot. In the case of flues from ovens, furnaces, steam boilers, closed fires used for any purpose of trade, or for the cooking apparatus of any hotel or eating house, the flues must have brickwork at least 8½ inches (0·22 m.) thick surrounding the same from the floor to the level of the ceiling of the room next above the room in which the fireplace is situated. This is a most important matter. Flues from steam boilers or hot air engines must not be less in height than 20 feet (6·1 m.) above the floor upon which the engine is placed. The inside of every flue and also the *outside*, where passing through any floor or roof or behind or against any woodwork, must be rendered, pargetted, or lined with fire-resisting piping of stoneware. The position and course of every flue in a party wall should be distinguished in a durable manner on the outside as it is carried up, except when the flue forms part of an external wall.

Chimney flues and brickwork surrounding flues in houses must be at least half a brick or 4½ inches (0·11 m.) in thickness, and the six highest courses built in cement, also the back of every fireplace opening in a party wall, from the hearth up to a height of 12 inches (0·3 m.) above the mantel, must be one brick (0·22 m.) in thickness.

Hearth stones or concrete slabs should be not less than 6 inches (0·15 m.) longer on each side than the width of the chimney opening, and should project into the room 18 inches (0·46 m.).

Hearth stones must be laid upon concrete or brick trimmer arches, and the hearth with the bedding must not be less than 6 inches (0·15 m.) thick.

Timber or woodwork must not be placed nearer than 12 inches (0·3 m.) to the inside of a flue or chimney opening, or within 10 inches (0·25 m.) from the upper surface of the hearth (see Chapter I., p. 47, and Chapter IV., p. 119) or within 2 inches (0·05 m.) from the face of the brickwork round a flue, unless the brickwork is rendered.

Wooden plugs must not be driven in nearer than 6 inches (0·15 m.) or any iron holdfasts or other fastenings nearer than 2 inches (0·05 m.) to the inside of any flue or chimney.

GENERAL.

In the latter part of this chapter reference was made to the fact that the London Building Act requires large areas of buildings to be divided by division walls, for the purpose of cutting the risk up into sections. Openings in the walls, when such are allowed, must be protected by double fire-resisting doors or shutters at a distance apart of not less than one-fourth of the full width of the opening; but it is obvious that in retail shops such doors must be kept open during business hours, at the very time the public requires protection. There is also the danger of persons being caught in one section of a building by the smoke from even a small outbreak of fire in another section; therefore partitions of hardwood are allowed in connection with the iron doors. They can be glazed with fire-resisting glass and made quite pleasing in appearance.

The floor under any oven, copper, steam-boiler, or stove, which is not heated by gas, and the floor round the same for a space of 18 inches (0·46 m.), should be of an incombustible and non-conducting nature, not less than 6 inches (0·15 m.) thick.

Pipes for conveying smoke should not be fixed nearer than 9 inches (0·23 m.) and for conveying heated air or steam, not nearer than 6 inches (0·15 m.), and hot water pipes not nearer than 3 inches (0·08 m.), to any combustible material unless they are properly lagged.

Floors above furnaces and within 18 inches (0·46 m.) of the crown of an oven should be of fire-resisting materials.

New buildings have been subject to a certain amount of control by local authorities under the powers granted them by the Public Health Act, 1875. From a fire point of view, most of the bye-laws are made under section 157, and are restricted in scope, viz., "with respect to the structure of walls, foundations, roofs, and chimneys of new buildings for securing stability and the prevention of fires, and for purposes of health."

London has its building Acts, and some of the larger towns have local Acts in force, either taking the place of bye-laws or giving supplementary powers to enforce regulations covering more details of construction than are permitted under the above section.

The term "new building" is explained in section 159 of the Public Health Act, 1875. It includes

(a) The re-erection of a building from below ground floor level.

(b) Any framed building, of which only the framework is left, down to the ground floor.

(c) Conversion into a dwelling-house of a building not originally constructed for human habitation.

(d) Divisions of one dwelling-house into several, such as flats.

All these buildings must be dealt with and approved as "new buildings" under the 1875 Act. As will be seen, such re-erection and conversion must inevitably mean a change of user, and, as mentioned elsewhere in this work, "change of user" is a most important consideration from a fire risk point of view, particularly with regard to means of escape.

The principles set out in the bye-laws are to cause proper separation between risks by the use of party walls. These walls must be solid and free of timber, in no case less than 9 inches (0·23 m.) thick, carried through and above the roof, but in some districts it is deemed sufficient if carried up to and well jointed close under the slates or other covering. In the last few years 4½-inch (0·11 m.) walls have been allowed between dwellings, built under the Government housing scheme.

In London, buildings (except churches and chapels) must not generally exceed in height the width of the street in front, except by consent of the Council, and all buildings are restricted to a height of 80 feet (24 m.) exclusive of two storeys in the roof.

Party walls of buildings of the warehouse class over 30 feet (9·1 m.) high must be carried up 3 feet (0·91 m.) above the roof, not less than 8½ inches (0·22 m.) in thickness, and in any other buildings of that height, 15 inches (0·38 m.) measured at right angles to the slope of the roof or gutter.

In a domestic building, any storey the floor of which is over 60 feet (18·3 m.) above the street level, must be constructed of fire-resisting materials throughout, and provided with proper means of escape in the case of fire for the persons dwelling or employed therein.

Buildings used for trade or manufacture shall not exceed 250,000 cubic feet (7,079 $m.^3$) unless separated by division walls. Exemptions may be granted in cases where the Architect to the L.C.C. and the Chief Officer of the Fire Brigade report that additional cubic extent is necessary, and that proper arrangements have been made and maintained for lessening so far as practicable, any danger from fire; but this consent is only in force so long as the building is used for the same trade as it was when the original permission was granted. It is allowed in cases where the floors are constructed in such a manner and of such materials, etc., as the Council may deem sufficiently satisfactory to entitle such floors to be considered as division walls, and thus allow a building to be divided horizontally into several sections of 250,000 cubic feet (7,079 $m.^3$).

The introduction into this country of the American steel framed building has necessitated the remodelling of many regulations. However, as these are of such a complicated nature, it would be altogether impossible to give them in detail in a work of this kind.

Fire-resisting construction as applied to floors, staircases, doors, partitions, windows, and, above all, office fittings, has received most careful consideration, and has been the subject of many patents, many of which are good, others indifferent.

All doors of office buildings and factories should open outwards.

Provision should be made when buildings are carried upon iron girders

over large shop windows that the girders and stanchions are properly protected from the effect of any fire that may occur in the shop.

The most up-to-date fire-resisting building can be, and often is, rendered dangerous by the indiscriminate cutting of holes in the walls and floors.

Fire-resisting glazing in proper frames will stand a considerable heat, and this type of glazing should be used in all areas and external walls that are within 20 feet (6·1 m.) of openings into other buildings. In American office buildings, the desks, shelves, and cupboards, and most of the other fittings, are made of steel.

Every cubic foot of timber and other combustible material used in the construction or the fitting up of a building, furnishes fuel for fire.

The reckless driving of wooden plugs into walls, and particularly into flues and chimneys should be prohibited now that blocks of Breeze bricks can be built in at intervals, and plug fastenings can be obtained that do not displace the joints of the brickwork.

Rooms that are lit by skylights or lanterns only should have some means of escape provided other than the door in case of fire.

The Fire Insurance Companies have fixed standards for fire-resisting construction. They are numbered I*a*, I*b*, II., III., and IV., and are of varying strictness, Nos. I*a* and I*b* being the most severe; but at the same time they carry the largest discount on the Insurance premium. Standard I*a* applies to cotton, flax, woollen and worsted mills. Being of importance they are given below :—

Standard I*b*.	Standard II.	Standard III.
The standard I*b* requires that buildings be not more than 80 feet in height and cubic contents of any one compartment not to exceed 60,000 cubic feet.		
Walls to be of brick, terra-cotta, or concrete, and not less than 13 inches thick, but if plain concrete, not less than 20 inches.	Ditto, but not less than 13 inches thick.	Solid brick, masonry and/or concrete devoid of cavity, but not less than 9 inches thick.
Partitions to be of incombustible material, excepting only office enclosures which are to be of hard non-resinous wood.	Ditto, but partitions of metal lathing and plaster on wood frame allowed.	
All flues to have brickwork not less than 9 inches thick towards the interior, and no woodwork to rest in or be plugged into the brickwork of any flue.	Ditto, but if rendered with 1 inch cement, brickwork may be 4½ inches.	
Openings in external walls not to exceed half the area of any storey.	Ditto.	

STANDARD I*b*.—*Contd.*	STANDARD II.—*Contd.*	STANDARD III.—*Contd.*
All window frames and sashes to be of iron or other hard metal, and all windows above ground floor to be glazed with glass not less than ¼ inch thick in sections not larger than 2 feet sup., and all openings above the ground floor opposite, and within 20 feet of any window or other glazed opening, and within 20 feet of any roof to be protected by "Fireproof" shutters or doors.	Ditto, but in lieu of "Fireproof" shutters wired glass may be used subject to certain conditions.	
Floors to be brick arches, terra-cotta, fireclay, or concrete not less than 6 inches thick.	Ditto.	Brick masonry, terra-cotta fireclay, concrete 4 inches thick devoid of cavity or hollow blocks with an aggregate thickness of 5 inches of solid material carried on metal joists, girders, columns, walls of piers of brick, masonry, or concrete.
Wooden flooring permitted if laid close to floor with no space.	Ditto.	Ditto.
Solid wood floors, not less than 9 inches thick, if ceiled with plaster and covered with floor boards (no space), are also allowed, provided water-proof lining is provided underneath the floor boards	Ditto.	
Scuppers to carry off water to be provided of 21 square inches every 12 feet apart on each floor (buildings in C. of L. or L.C.C., scuppers not essential)	Ditto.	
Roofs to be entirely of incombustible materials as for floors, but not less than 4 inches thick Glass not less tnan ¼ inch thick, in sections not exceeding 36 square inches, set in hard metal and wired glass and electro-copper glazing considered as incombustible.	Roofs to be entirely of incombustible material, glass allowed in roof if not less than ¼ inch thick not exceeding 5 feet sup., or wired glass or electro-copper glazing in each case, set in hard metal. Outlets to meet requirements of Factory and Workshop Acts allowed subject to certain conditions.	Having no combustible material in its construction.

STANDARD I*b*.—*Contd.*	STANDARD II.—*Contd.*	STANDARD III.—*Contd.*
Structural Metalwork.—All columns and stanchions to be covered with brickwork or porous terra-cotta 2 inches thick, or concrete or plaster 1½ inches thick, keyed into metal supports and protected for a height of 4 feet from floor where cement concrete or plaster only used.	All columns, stanchions, girders, joists, lintels, and other metal work (*excluding* framework of roofs), to be cased 2 inches thick or with 1 inch concrete or plaster as Standard I*b*.	
All other metal work including roof work to be encased in porous terra-cotta 2 inches thick, securely anchored, or cement concrete or plaster 1 inch thick keyed into metal supports. Provision to be made in all cases for expansion.		
ROOFS AND CEILINGS.		
No lining of wood or textile fabric allowed to any part of walls, partitions, ceilings, or roof.	Ditto, except dado allowed in wood not exceeding 6 feet high in offices, cellars, staircases, passages, or salerooms, provided not used for storage.	
FLOOR OPENINGS.		
Only holes for driving shafts, iron or earthenware tubes for electric conductors, and these to be specially dealt with.	Ditto.	Ditto.
Staircases practically as required for emergency exits by L.C.C. Where staircases and hoists extend to top floor, enclosure must be roofed with glass roof protected (subject to certain restrictions in L.C.C. area).	Ditto.	Hoists to be enclosed in walls of 6 inches concrete or R.C. 3 inches thick with Fire-resisting doors. Spouts or Trunks not exceeding 4 square feet in area constructed of iron $\frac{1}{16}$ inch thick, and shutters to every opening.
All belting and rope races to be enclosed as for staircases and hoists.	Ditto.	
Shafting through walls to fit closely into wall, and to have closed wall boxes leaving no open space.	Ditto.	Openings up to 12 square feet with double iron or metal covered trap doors (special construction).

Standard Ib.—*Contd.*	Standard II.—*Contd.*	Standard III.—*Contd.*
Pipes, etc. No wooden casing allowed. All pipes (except water pipes not exceeding 1½ inches diameter to be of hard metal).	Ditto.	Staircases having steps and landings of brick, stone, iron, concrete, enclosed with walls, this applying also to Vent shafts, all openings being protected.
COMMUNICATING COMPARTMENTS.		
Two or more compartments (constructed according to the rules), may communicate provided their aggregate cubical contents do not exceed 60,000 cubic feet. When cubic contents exceed 60,000 cubic feet, communication only allowed across a fireproof compartment, built up from the basement with walls of solid brickwork, and having all openings protected by fireproof doors at least 6 feet apart.		
REINFORCED CONCRETE.		
Reinforced concrete buildings allowed subject to the usual precautions.	Ditto.	Ditto.
The requirements as to proportion of cement in the concrete is somewhat ambiguous, viz. :—		
"In the proportion of 6 cwts. of cement to each cubic yard of concrete."	Ditto.	Ditto.
All external walls to be not less than 6 inches thick.	Ditto.	Between piers 5 inches ditto.
Division walls 8 inches thick.		
Party walls 13 inches thick except if adjoining reinforced concrete building then 8 inches thick.	Ditto.	
Flues 4 inches thick if lined with fire tiles 1½ inches thick.	Ditto	

STANDARD Ib.—*Contd.*	STANDARD II.—*Contd.*	STANDARD III.—*Contd.*
Floors 5 inches thick and supported on beams and columns of reinforced concrete.	Ditto.	Ditto, but 4 inches thick.
Roofs 3 inches thick.	Ditto.	
No metal to be nearer face than double its diameter, but not less than 1 inch and need not exceed 2 inches.	Ditto.	
Enclosures and staircases and hoists 6 inches thick.		
Fire-resisting compartments to have walls 8 inches and floors 5 inches thick.		

Under Standard IV., the Party and External walls to be not less than 9 inches thick, of brickwork, etc., and no combustible material to enter into any part of construction except the roofing, doors, and window frames.

External walls of reinforced concrete, 5 inches thick.

Hoist enclosure to be of incombustible construction.

Staircases may have steps and landings of hardwood.

It is important to note that in all the Standards all concrete is to be cement concrete, and that coke breeze and similar material is not allowed as an aggregate.

The Insurance Companies' regulations as to fireproof doors and shutters are many and various, they deal with Iron and Steel (sliding and hinged). Metal-covered doors (sliding and hinged). "Check fire" doors (sliding and hinged). Ferro-concrete doors, etc.

The openings must not exceed 56 feet super., and must not be more than 7 feet in width or 9 feet in height.

In some cases they may not exceed 45 feet super., nor be more than 6 feet in width, nor 9 feet in height.

In other cases 35 feet super., and not more than 5 feet in width or 7 feet in height.

These rules generally are very carefully drawn and apply to fixing, and other little details, all of which are of the greatest importance.

The use of cast-iron for door parts or fittings is not allowed.

Each door must have a metal plate attached, giving the date of its erection, and in some cases the name of the maker. The fixing and method of securing fireproof doors and shutters is of the utmost importance.

The proper maintenance of buildings should receive greater care than is usual, and the periodical examination of appliances and doors and shutters for preventing the spread of fire should be insisted upon.

Many risks would be avoided, and much loss saved if all buildings were inspected and reported on every 6 or 12 months.

Unfortunately, most people rely only upon the Insurance Companies' inspections, which is not fair to any of the parties interested, particularly from the Employee's point of view.

All the particulars given above as to Insurance Companies' requirements are, of course, subject to other rules as to special work, Artificial Lighting, etc.

There are many considerations to take into account when settling what form of construction to adopt. One immediate point is the comparative first cost, but this should be considered in relation to the reduction in Insurance premium, and also the possible inconvenience to the works, and the loss of profit and loss of business connection in the event of a fire. The Local Authorities make requirements as to exit for Employees, and the Insurance Companies more particularly as to fire risk, but speaking generally the better the Insurance risk the less risk to Employees. It is only the Owner who can determine the value of the latter points. The Insurance Company determine the question of premiums. It is interesting to note that premiums can, under certain circumstances, be reduced as much as 60 per cent. This is where large and valuable stocks are kept and may be of great importance.

This leads on to the question of precautions for extinguishing fires, and large reductions in premiums are possible if care is taken as to these precautions, ranging from 5 to 60 per cent.

For fire extinguishing we have, speaking broadly, the following :—

Chemicals (dry and liquid).
Water (high and low pressures).
Steam.
Sand.

And in addition various methods of smothering with sheets or blankets formed of various materials.

There are comparatively few large chemical machines, but generally these appliances take the form of small portable Extincteurs, and no doubt, in very many cases, they have proved exceedingly useful, and saved considerable loss.

PART V.—MISCELLANEOUS.

CHAPTER XIX.

RECIPES—MENSURATION—QUOTATIONS.

Fire Proofing.—Solutions useful for rendering goods of an absorbent nature fire-resisting.

For light stuffs: sulphate of ammonia 8 lbs., carbonate of ammonia $2\frac{1}{2}$ lbs., boracic acid 3 lbs., borax 2 lbs., starch 2 lbs., dextrine* or gelatine $\frac{1}{2}$ lb., water 100 lbs.; use at 86° F. (30° C.).

For scenery and light woodwork: ammonium chloride 15 lbs., boracic acid 5 lbs., fish glue 50 lbs., gelatine $1\frac{1}{2}$ lbs., water 100 lbs., and chalk sufficient to give a suitable consistency: apply two or three coats with a brush, at from 122° F. (50° C.) to 140° F. (60° C.).

For cordage, etc.: ammonium chloride 15 lbs., boracic acid 6 lbs., borax 3 lbs., water 100 lbs., steep for 15 or 20 minutes at 212° F. (100° C.).

For paper (printed or not): sulphate of ammonia 8 lbs., boracic acid 3 lbs., borax 2 lbs., water 100 lbs.

A solution composed of—

Phosphate of ammonia,	1 lb.,
Chloride of ammonia,	2 lbs.,
Water,	$1\frac{1}{2}$ gallons,

has been found to render efficiently fire-resisting many fabrics.

It is always advisable to try any solution on a sample of the textile to be treated before dealing with a large quantity. If the result of the test is satisfactory and has not injured the material or affected its colour, the bulk can then be treated.

As most of the antipyrenes are hygroscopic, great care is required in treating valuable articles.

The British Fire Prevention Committee's Red Books give the results of many exhaustive tests with fire-resisting solutions.

Poison for Rats.—A poison that is deadly to rats but comparatively harmless to live stock in the small baits that serve their primary purpose is carbonate of barium. One part of carbonate of barium, with one part of grated cheese, one of fat and one of meal, makes a deadly bait.

* Dextrine is prepared by heating starch, and is a product of the action of malt extract on starch. It is soluble in water and insoluble in alcohol, and is white in colour. It is also used commercially for gumming envelopes, etc. Anything of an adhesive nature should answer for the purpose.

Polish.—Mixture for coating linoleum, oil cloth, and hard wooden floors—

2 oz. Beeswax,
1 oz. White wax,
½ oz. Castile soap,
½ pint turpentine,
½ pint water.

Shave the wax very finely and put into a jar with the turpentine. Shave the soap very finely and put into a second jar with the water. Set aside in a warm place until each lot is dissolved, stir occasionally. When quite dissolved mix both solutions together and bottle. Upon no account must it be put upon a stove as it is highly inflammable.

Repair of Canvas Hose.—Canvas hose can be repaired by stitching up the holes and afterwards covering the same with a patch of sail canvas. A solution used for attaching the patch to the hose is made up of one part of pure gutta-percha and two parts of bi-sulphide of carbon. The gutta-percha is chopped up, and placed in an earthenware receptacle, into which the bi-sulphide of carbon is poured, the jar standing in a bucket of nearly boiling water. For some time continual stirring is necessary, with the stirrer through a loose fitting cover, in order that the gas of the bi-sulphide of carbon may not evaporate too quickly. The greatest care must be taken in mixing this solution, as the bi-sulphide of carbon is very inflammable, and gives off not only an unpleasant, but dangerous gas, and, therefore, should on no account be left unattended at any time. After the solution is made it must be kept in a stoppered jar, and, when cold, smeared over the portion of hose to be patched and over the canvas for the patch. This must be allowed to dry, which takes about an hour, and this procedure twice repeated so as to have three coats in all. After the gutta-percha is thoroughly dry both the hose and patch are heated by suspended irons, until quite sticky, and then placed face to face and well rubbed together in order to force out any air so that the smallest particle of solution remains between the two fabrics. The patches are then placed under pressure until cold. Ready prepared canvas and studs can now be obtained that are useful for patching hose in which a solution is used that does not require heating and is free from the danger attendant with the use of bi-sulphide of carbon.

To Cement Rubber to Leather.—It is sometimes required to cement rubber to leather. The following is a good way, says the "American Blacksmith": Roughen both surfaces with a sharp glass edge, apply on both a diluted solution of gutta-percha in carbon di-sulphide and let the solution soak into the material. Then press upon each surface a skin of gutta-percha $\frac{1}{100}$ of an inch in thickness, between rolls. Unite the two surfaces in a press that should be warm but not hot. In case a press cannot be used, cut 30 parts of rubber into small pieces and dissolve it in 140 parts of carbon disulphide, the vessel being placed on a water bath of 86° F. (30° C.). Melt 10 parts of rubber with 15 parts of rosin and add 35 parts of oil of turpentine. When the rubber has been completely dissolved, the two liquids may be mixed. The resulting cement must be kept well corked.

The above are given as being used by brigades, but upon account of the very dangerous nature of carbon di-sulphide it is strongly recommended that the ordinary

rubber solutions (more particularly one with chlorinated hydrocarbon base) which can be obtained at any motor store should be used.

Foamite Extinguisher.—A good foam for extinguishers can be made with—

Powder,
 $1\frac{1}{4}$ lbs. of sodium bi-carbonate,
 $\frac{3}{4}$ oz. crude saponin (in powder).
Liquid,
 30 oz. sulphuric acid, S.G. 1·32.
Mix the powder in a quart of hot water to dissolve it and then add 7 quarts of cold water.
The acid should be covered in its bottle by a little mineral lubricating oil.

The proportions for the chemicals used in these extinguishers as given in the *Bulletin* of the Bureau of Mines, No. 170, 1918, U.S. Department of Interior, are as follows:—

SOLUTION OR POWDER A.

	Proportions by Weight. Recipe 1.	Recipe 2.	Recipe 3.
Aluminium Sulphate (Crystals),	10	11	12
Sulphuric Acid (66° B.),	$\frac{1}{2}$	—	—
Extract of Liquorice Powder,	—	3	—
Acetic Acid,	—	—	$\frac{1}{2}$
Ground Glue,	—	—	1
Glucose,	—	—	$\frac{1}{4}$
Water,	100	100	100

SOLUTION OR POWDER B.

	Proportions by Weight. Recipe 1.	Recipe 2.	Recipe 3.
Bi-carbonate of Soda,	$7\frac{1}{2}$	$9\frac{1}{4}$	10
Ground Glue,	$1\frac{1}{4}$	—	1
Glucose,	$\frac{1}{2}$	—	$\frac{1}{4}$
Arsenious Oxide,	$\frac{1}{32}$	—	—
Water,	100	100	100

The same publication indicates that the Foamite Chemicals were:—

(A)

Aluminium Sulphate	13 %
Water,	87 „
	100 „

(B)

Foamite,	3 %
Bi-carbonate of Soda,	8 „
Water,	89 „
	100 „

The chemical action can be expressed in general terms as follows:—

$$Al_2(SO_4)_3 + H_2O + 6NaHCO_3 + \text{Foamite or Liquorice extract, etc.}$$
$$= 2Al(OH)_3 + 3Na_2SO_4 + H_2O + 6CO_2.$$

The soda acid chemical action is as follows:—

$$2NaHCO_3 + H_2SO_4 = 2CO_2 + Na_2SO_4 + 2H_2O.$$

The atomic weights of the various chemicals are:—

H = 1.	Na = 23.
O = 16.	S = 32.
C = 12.	Al = 27.

MATHEMATICS AND TABLES.

So long as a large portion of school time is occupied in teaching young people that 16 drachms and 37½ grains make one ounce, that 8 galls. make a bushel and 9 galls. a firkin, 16½ feet one pole, rod, or perch, and many other legal facts, there will not be time to instruct the students in useful mathematics. It is, therefore, necessary even in a work like this to set out tables, etc., that could be dispensed with if the resolution were complied with which was passed at the Conference of Statesmen from every part of the Empire in 1902, viz.:—"That it is advisable to adopt the metric system of weights and measures for use within the Empire, and the Prime Ministers urge the Governments represented at this Conference to give consideration to the question of its early adoption." It has not been done, and thus our trade is fast passing to more enlightened countries.

Hydraulics.—As in some of the calculations in hydraulics mention is made of the fifth power of numbers, it may not be out of place to state that it means the number used as a factor or multiplier 5 times, thus:—

A number, say 7, is the original number to be used as a factor once,

,,	$7\times7 =$	49 is the square or 2nd	power, shown thus			7^2,
,,	$7\times7\times7 =$	**343** is the cube or 3rd	,,	,,		7^3,
,,	$7\times7\times7\times7 =$	**2,401** is the 4th	,,	,,		7^4,
,,	$7\times7\times7\times7\times7 =$	**16,807** is the 5th	,,	,,		7^5,

and so onwards.

The accepted authority in practical hydraulics is Thomas Box, whose book of rules and tables should be familiar to all engineers and persons having to do with the discharge of water through pipes.

Logarithms.—To obtain results that may be considered fairly satisfactory a number of calculations are required, and in order to work them easily it is required to use logarithms.

The logarithm of a number (abbreviated to log.) to a given base is the index of the power to which that base must be raised to give the number. It is divided into two parts, the whole number called the **characteristic** and a decimal called the **mantissa.** These names were given in about the year A.D. 1550, when the principle on which logarithms are based was worked out. Mantissa is an old Latin word meaning a little addition. Tables of logarithms can be purchased from any seller of technical books.

The most generally used formula for iron pipe is that of Box, which has the merit of erring on the side of safety.

As mentioned above, several calculations are necessary.

To find the Velocity of Flow $V = \sqrt{H} \times 8$

In which H = the height or head of water in feet, and
V = the velocity in feet per second.

Friction of long straight pipes, $G = \left(\frac{(3d)^5 \times H}{L}\right)^{\frac{1}{2}}$. $H = \frac{G^2 \times L}{(3d)^5}$.

In which d = diam. of pipe in inches.
L = length in yards.
H = head of water in feet.
G = gallons per minute.

Loss of Head by Bends is considerable, and may be calculated—

$$H = \left\{ \cdot131 + \left(1\cdot847 \times \left(\frac{r}{R}\right)^{\frac{7}{2}}\right) \right\} \times \frac{V^2 \times \varphi}{960},$$

and

$$V^2 = \frac{960 \times H}{\varphi \times \left\{ \cdot131 + \left(1\cdot847 \times \left(\frac{r}{R}\right)^{\frac{7}{2}}\right) \right\}}.$$

In which H = the head due to change of direction, in inches.
r = radius of the bore of the pipe, in inches.
R = radius of the centre line of the bend, in inches.
φ = angle of bend in degrees.
V = velocity of discharge, in feet per second.

Quantity Discharged through a Nozzle.—The rule for ascertaining this is $G = \sqrt{H} \times d^2 \times \cdot24$, where G = the number of gallons per minute, H = head of water in feet on the nozzle (not at the engine or hydrant), and d = diameter of the nozzle in eights of an inch.

The quantity of water discharged, the amount of head lost by friction, and the velocity of flow, are all affected in other ways than those we have mentioned, but not to so great an extent. As before stated, "Practical Hydraulics," by Thomas Box, should be studied, the tables given will be found most useful to firemen, although given for theoretical flows and for iron pipes in straight lines. The author has found in practice that the head of water consumed by friction given by Box for iron pipes 3 inches in diameter, was equal to the results obtained through 2¾-inch rubber lined canvas hose (see p. 103). By referring to the results obtained by Mr. J. R. Freeman and set out in Chapter III., the student may *approximately* find the loss of pressure due to friction in different kinds of hose.

Heights of Jets.—The rule is $h^1 = \frac{H^2}{d} \times \cdot0125$. Where h^1 = the difference between the feet head at the nozzle and the height of the stream in feet, H the pressure upon the nozzle in feet head, and d the diameter of the nozzle in eighths of an inch.

Sizes of Jets for Given Quantities and Pressures.—The rule is $D = \sqrt{\frac{G}{\cdot24\sqrt{H}}}$, where G = gallons per minute, H = head in feet on the nozzle, and D = diameter of nozzle in eighths of an inch.

Remember that the American gallon is not the same as the English, 100 British imperial gallons are equal to 120 American gallons.

Avoirdupois Weight.

Drachms.	Ounces.	Lbs.	Qrs.	Cwts.	Tons.	Metric Grammes.
1	= ·0625	= ·0039	= ·000139	= ·000035	= ·00000174	= 1·771846
16	= 1	= ·0625	= ·002232	= ·000558	= ·000028	= 28·34954
256	= 16	= 1	= ·0357	= ·00893	= ·000447	=453·59
7,168	= 448	= 28	= 1	= ·25	= ·0125	=12,700
28,672	= 1,792	= 112	= 4	= 1	= ·05	=50,802
573,440	= 35,840	= 2,240	= 80	= 20	= 1	=1,016,048

Long Measure.

Ins.	Feet.	Yards.	Faths.	Poles.	Furls.	Mile.	Metres.
1	= ·083	= ·02778	= ·0139	= ·005	= ·000126	= ·0000158	= ·0254
12	= 1	= ·333	= ·1667	= ·0606	= ·00151	= ·0001894	= ·3048
36	= 3	= 1	= ·5	= ·182	= ·00454	= ·000568	= ·9144
72	= 6	= 2	= 1	= ·364	= ·0091	= ·001136	= 1·8287
198	= 16½	= 5½	= 2¾	= 1	= ·025	= ·003125	= 5·029
7,920	= 660	= 220	= 110	= 40	= 1	= ·125	= 201·16
63,360	= 5,280	= 1,760	= 880	= 320	= 8	= 1	= 1609·33

Measure of Capacity.

Pints.	Galls.	Peck.	Bushel.	Quarter.	Wey.	Last.	Cubic Feet.	Litres.
1	= ·125	= ·0625	= ·01562	= ·00195	= ·00039	= ·000195	= ·02	= ·5676
8	= 1	= ·5	= ·125	= ·0156	= ·00312	= ·00156	= ·1604	= 4·543
16	= 2	= 1	= ·25	= ·03125	= ·00625	= ·00312	= ·3208	= 9·082
64	= 8	= 4	= 1	= ·125	= ·025	= ·0125	= 1·283	= 36·328
512	= 64	= 32	= 8	= 1	= ·2	= ·1	= 10·264	= 290·625
2,560	= 320	= 160	= 40	= 5	= 1	= ·5	= 51·319	= 1,453·126
5,120	= 640	= 320	= 80	= 10	= 2	= 1	= 102·64	= 2,906·25

Multipliers for Converting British Measures

	Links into Feet.	Feet into Links.	Square Links into Square Feet.	Square Feet into Square Links.	
1	0·66	1·51515	0·4356	2·2957	1
2	1·32	3·03030	0·8712	4·5914	2
3	1·98	4·54545	1·3068	6·8871	3
4	2·64	6·06061	1·7424	9·1827	4
5	3·30	7·57576	2·1780	11·4784	5
6	3·96	9·09091	2·6136	13·7741	6
7	4·62	10·60606	3·0492	16·0698	7
8	5·28	12·12121	3·4848	18·3655	8
9	5·94	13·63636	3·9204	20·6612	9
10	6·60	15·15152	4·3560	22·9568	10

MULTIPLIERS FOR CONVERTING BRITISH MEASURES—*Contd.*

	Lbs. Avoir. into Grains.	Grains into Lbs. Avoir.	Cubic Feet into Gallons.	Gallons into Cubic Feet.	
1	7,000	0·000142857	6·2355	0·16037	1
2	14,000	0·000285714	12·4710	0·32074	2
3	21,000	0·000428571	18·7065	0·48112	3
4	28,000	0·000571429	24·9420	0·64149	4
5	35,000	0 000714286	31·1775	0·80186	5
6	42,000	0·000857143	37·4130	0·96223	6
7	49,000	0·001000000	43·6485	1·12260	7
8	56,000	0 001142857	49·8840	1·28298	8
9	63,000	0·001285714	56·1195	1·44335	9
10	70,000	0 001428571	62·3550	1·60372	10

	Mean Geographical Miles into Statute Miles.	Statute Miles into Mean Geographical Miles.	Tons into Lbs.	Lbs. into Tons.	
1	1·151	0·869	2,240	·0004464	1
2	2·302	1·738	4,480	·0008929	2
3	3·452	2·607	6,720	·0013393	3
4	4·603	3·476	8,960	·0017857	4
5	5·754	4·345	11,200	·0022321	5
6	6·905	5·214	13,440	·0026786	6
7	8·056	6·083	15,680	·0031250	7
8	9·207	6·952	17,920	·0035714	8
9	10·357	7·821	20,160	·0040179	9
10	11·508	8·690	22,400	·0044643	10

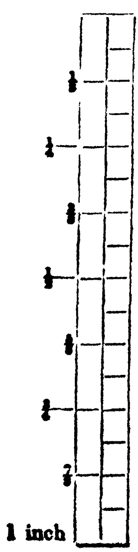
	Tons Displacement into Cubic Feet.	Cubic Feet into Tons Displacement.	Lbs. on the Square Inch into Lbs. on the Square Foot.	Lbs. on the Square Foot into Lbs. on the Square Inch.	
1	35	·02857	144	·00694	1
2	70	·05714	288	·01389	2
3	105	·08571	432	·02083	3
4	140	·11429	576	·02778	4
5	175	·14286	720	·03472	5
6	210	·17143	864	·04167	6
7	245	·20000	1,008	·04861	7
8	280	·22857	1,152	·05556	8
9	315	·25714	1,296	·06250	9
10	350	·28571	1,440	·06944	10

Values of Farthings, Pence, and Shillings in Decimal Fractions of a Pound.

Farthings.	£.
1	·0010417
2	·0020833
3	·0031250
Pence.	
1	·004167
1½	·006250
2	·008333
3	·012500
4	·016667
4½	·018750
5	·020833
6	·025000
7	·029167
7½	·031250
8	·033333
9	·037500
10	·041667
10½	·043750
11	·045833

Shillings.	£.
1	·05
2	·10
3	·15
4	·20
5	·25
6	·30
7	·35
8	·40
9	·45
10	·50
11	·55
12	·60
13	·65
14	·70
15	·75
16	·80
17	·85
18	·90
19	·95

Decimal Equivalents of Inches, Feet, and Yards.



Fractions of of an Inch.	Decims. of an Inch.		Decims. of an Foot.
	·0625	=	·00521
	·125	=	·01041
	·1875	=	·01562
	·25	=	·02083
	·3125	=	·02604
	·375	=	·03125
	·4375	=	·03646
	·5	=	·04166
	·5625	=	·04687
	·625	=	·05208
	·6875	=	·05729
	·75	=	·06250
	·8125	=	·06771
	·875	=	·07292
	·9375	=	·07812
1 inch	1·00	=	·08333

Inches.		Feet.		Yards.
1	=	·0833	=	·0278
2	=	·1666	=	·0556
3	=	·25	=	·0833
4	=	·3333	=	·1111
5	=	·4166	=	·1389
6	=	·5	=	·1667
7	=	·5833	=	·1944
8	=	·6666	=	·2222
9	=	·75	=	·25
10	=	·8333	=	·2778
11	=	·9166	=	·3056
12	=	1·000	=	·3333

Yards Expressed as the Decimal of a Mile.

	Units.	Tens.	Hundreds.	Thousands.
1	·0005682	·005682	·05682	·56828
2	·0011364	·011364	·11364	...
3	·0017046	·017046	·17046	...
4	·0022728	·022728	·22728	...
5	·0028410	·028410	·28410	...
6	·0034092	·034092	·34092	...
7	·0039774	·039774	·39774	...
8	·0045456	·045456	·45456	...
9	·0051138	·051138	·51138	...

METRIC SYSTEM.

In the Metric System of Weights and Measures the
Standard Unit of Weight is the Gramme.
„ „ of Length is the Metre.
„ „ of Capacity is the Litre.

Multiples of these units are in decimal progression and are distinguished by Greek prefixes while the sub-divisions are designated by Latin prefixes, thus,

Weight.		Length.	Capacity.	
·001 = $\frac{1}{1000}$	Milligramme.	Millimetre.	Millilitre.	$\frac{1}{1000}$ = ·001
·01 = $\frac{1}{100}$	Centigramme.	Centimetre.	Centilitre.	$\frac{1}{100}$ = ·01
·1 = $\frac{1}{10}$	Decigramme.	Decimetre.	Decilitre.	$\frac{1}{10}$ = ·1
Gramme.		Metre.	Litre.	
10	Dekagramme.	Dekametre.	Dekalitre.	10
100	Hektogramme.	Hektometre.	Hektolitre.	100
1,000	Kilogramme.	Kilometre.	Kilolitre.	1,000

Abbreviations—

cm. = centimetre.		C. = Centigrade.	
$cm.^2$ = square centimetre.		F. = Fahrenheit.	
$cm.^3$ = cubic centimetre.		° = degrees.	
g. = gramme.		C.° = degrees Centigrade.	
kg. = kilogramme.		F.° = degrees Fahrenheit.	
km. = kilometre.		°/。 = per cent.	
$km.^2$ = square kilometre.		+ = plus, addition.	
l. = litre.		— = minus, subtraction.	
m. = metre.		× = by, multiplied by.	
$m.^2$ = square metre.		÷ = divided by.	
$m.^3$ = cubic metre.		$\sqrt{}$ = square root.	
mm. = millimetre.		$\sqrt[3]{}$ = cube root.	
$mm.^2$ = square millimetre.		= = equals, equal to, becomes.	
$mm.^3$ = cubic millimetre.		log = logarithm.	

Approximate Values of British and French Measures.—One metre = 3·28 feet = 3 feet 3⅜ inches (all but $\frac{1}{512}$ inch) = 40 inches nearly ($\frac{1}{64}$ or 1·6 per cent. less).

One decimetre (·100 metre) = 4 inches nearly (exactly 3$\frac{15}{16}$ inches).

One centimetre (0·10 metre) = ·4 inch, or $\frac{1}{10}$ inch nearly.

One millimetre (·001 metre) = ·04 inch or $\frac{4}{100}$ inch, or ⅖ of $\frac{1}{10}$ inch or $\frac{1}{25}$ inch nearly.

One inch is about 2½ centimetres (exactly 2·54).

One inch is about 25 millimetres (exactly 25·4).

One yard is $\frac{11}{12}$ of a metre. Thus 11 metres are equal to 12 yards.

To convert metres into inches, multiply by 40.

To convert inches into metres, divide by 40.

One kilometre (1,000 metres) is about ⅝ of a mile (it is 0·6 per cent. less).

One mile is about 1⅝ kilometres (it is 1 per cent. less).

One square centimetre is about $\frac{1}{6\cdot5}$ part of a square inch, or ·155 square inch.

One square inch is 6·5 square centimetres.

One square metre contains nearly 11 square feet, or nearly 1⅕ square yards.

One square yard is nearly $\frac{5}{6}$ of a square metre.

One acre is over 4,000 square metres (it is about 1·2 per cent. more).

One square mile is nearly 260 hectares or metrical acres (10,000 square metres). It is about 0·4 per cent less.

One cubic yard is about ¾ cubic metre (it is 2 per cent. more).

One cubic metre is nearly 1⅓ cubic yards (it is 1⅔ per cent. less).

One cubic metre is nearly 35¼ cubic feet (it is ·05 per cent. less).

One litre is over 1¾ pints (it is 0·57 per cent. more).

One gallon contains above 4½ litres (it holds about 1 per cent. more).

One kilolitre (a cubic metre) holds nearly 1 ton of water at 62° F. (16·6° C.) (1¾ per cent. less).

One cubic foot contains 28·3 litres.

One gramme is nearly 15½ grains (about ½ per cent. less). One lb. at London = 445,000 dynes.

One kilogramme is about 2⅕ lbs. (about ¼ per cent. more).

One thousand kilogrammes, or a metric ton, is nearly one English ton (about 1½ per cent. less).

One hundred-weight is nearly 51 kilogrammes (⅘ per cent. less).

One kilogrammetre is = 7·233 ft. lbs.

One foot pound = ·138 kilogrammetre.

Inches and Fractions of Inches Converted into Metres

(Approximate).

Ins.	0	1	2	3	4	5	6	7	8	9	10	11	12
	..	·0254	·0508	·0762	·1016	·1270	·1524	·1778	·2032	2286	2540	·3793	·3047
$\frac{1}{16}$	·0015	·0269	·0523	·0777	·1032	·1286	·1539	·1793	·2047	2301	·2555	2809	$\frac{1}{16}$
$\frac{1}{8}$	·0031	·0285	·0539	·0793	·1047	·1301	·1555	·1809	·2063	·2317	·2571	·2825	$\frac{1}{8}$
$\frac{3}{16}$	·0047	·0301	·0555	0809	·1063	·1317	·1571	·1825	·2079	·2333	·2587	·2841	$\frac{3}{16}$
$\frac{1}{4}$	·0063	0317	·0571	·0825	·1079	·1333	·1587	·1841	2095	·2349	·2603	·2857	$\frac{1}{4}$
$\frac{5}{16}$	·0079	·0333	·0587	0841	·1095	1349	·1603	·1857	2111	2365	2619	·2873	$\frac{5}{16}$
$\frac{3}{8}$	0095	·0349	·0603	·0857	·1111	·1365	·1619	·1873	·2127	2381	·2635	·2889	$\frac{3}{8}$
$\frac{7}{16}$	·0111	·0365	·0619	·0873	·1127	·1381	·1635	·1889	2143	·2397	·2651	·2905	$\frac{7}{16}$
$\frac{1}{2}$	·0127	·0380	·0635	0888	1143	·1397	·1651	1905	·2159	2413	2667	2920	$\frac{1}{2}$
$\frac{9}{16}$	·0142	0396	·0650	·0904	·1158	·1412	·1666	1920	·2174	·2428	·2682	·2936	$\frac{9}{16}$
$\frac{5}{8}$	·0158	·0412	0666	0920	·1174	·1428	1682	·1936	2190	·2444	·2698	·2952	$\frac{5}{8}$
$\frac{11}{16}$	·0174	·0428	0682	0936	·1190	·1444	·1698	·1952	·2206	·2460	2714	·2968	$\frac{11}{16}$
$\frac{3}{4}$	0190	0444	·0698	·0952	·1206	·1460	·1714	·1968	·2222	2476	·2730	·2984	$\frac{3}{4}$
$\frac{13}{16}$	0206	·0460	0714	0968	1222	1476	·1730	·1984	2238	2492	2746	3000	$\frac{13}{16}$
$\frac{7}{8}$	0222	·0476	·0730	·0984	1238	1492	·1746	·2000	·2254	2508	2762	3016	$\frac{7}{8}$
$\frac{15}{16}$	0238	0492	·0746	1000	1254	·1508	·1762	·2016	2270	2524	·2778	3032	$\frac{15}{16}$
Ins.	0	1	2	3	4	5	6	7	8	9	10	11	Ins.

Table of Kilogrammes Equivalent to Lbs. Avoirdupois

(Approximate).

Lbs	Kilos. (Kg.).	Lbs.	Kilos. (Kg.).	Lbs.	Kilos (Kg.).	Lbs.	Kilos (Kg.).	Lbs	Kilos. (Kg.).
1 =	·4536	21 =	9·5255	41 =	18·5973	61 =	27·6691	81 =	36·7410
2 =	·9072	22 =	9·9790	42	19·0509	62 =	28·1227	82 =	37 1946
3 =	1·3608	23 =	10·4326	43	19·5045	63 =	28·5763	83 =	37·6482
4 =	1·8143	24 =	10·8862	44 =	19·9581	64 =	29·0299	84 =	38·1018
5 =	2·2680	25 =	11·3398	45 =	20·4117	65 =	29·4835	85 =	38·5554
6 =	2·7216	26	11·7934	46	20·8653	66 =	29·9371	86 =	39·0090
7 =	3·1751	27 =	12·2470	47 =	21·3189	67 =	30·3907	87 =	39·4626
8 =	3·6287	28	12·7000	48 =	21·7725	68 =	30·8443	88 =	39·9162
9 =	4·0823	29 =	13·1542	49 =	22·2260	69	31·2979	89	40·3697
10 =	4·5360	30 =	13·6078	50 =	22·6796	70 =	31·7515	90 =	40·8233
11 =	4·9895	31 =	14·0614	51 =	23·1332	71 =	32·2051	91 =	41·2769
12 =	5·4431	32 =	14·5150	52 =	23·5868	72	32·6587	92 =	41·7305
13 =	5·8967	33 =	14·9686	53 =	24·0404	73 =	33·1122	93 =	42·1841
14 =	6 3503	34 =	15·4222	54	24·4940	74 =	33·5658	94 =	42·6377
15 =	6·8039	35 =	15·8757	55 =	24·9476	75 =	34·0194	95 =	43·0913
16 =	7·2575	36 =	16·3293	56 =	25·4012	76 =	34·4730	96 =	43·5449
17 =	7·7111	37 =	16·7829	57 =	25·8548	77 =	34·9266	97 =	43·9985
18 =	8·1647	38	17·2365	58 =	26·3084	78 =	35·3802	98 =	44·4521
19 =	8·6183	39	17·6901	59 =	26·7620	79 =	35·8338	99 =	44·9057
20 =	9·0718	40 =	18·1437	60 =	27·2156	80 =	36·2874	100 =	45·5393

Table of Kilogrammes Equivalent to Lbs. Avoirdupois—*Contd.*

Lbs.	Kilos. (Kg.).	Lbs.	Kilos. (Kg.).	Lbs.	Kilos. (Kg.).	Lbs.	Kilos. (Kg.).	Lbs.	Kilos. (Kg.).
101 =	45·8129	111 =	50·3488	150 =	68·0	1,000 =	453·6	2,000 =	907·2
102 =	46·2665	112 =	50·8024	200 =	90·7	1,100 =	499·0	2,240 =	1,016·1
103 =	46·7201	113 =	51·2560	250 =	111·4	1,200 =	544·3	2,500 =	1,134·0
104 =	47·1736	114 =	51·7096	300 =	136·1	1,300 =	589·7	3,000 =	1,360·8
105 =	47·6273	115 =	52·1632	400 =	181·4	1,400 =	635·0	3,500 =	1,587·6
106 =	48·0809	116 =	52·6168	500 =	226·8	1,500 =	680·4	4,000 =	1,814·4
107 =	48·5344	117 =	53·0704	600 =	272·2	1,600 =	725·7	4,500 =	2,041·2
108 =	48·9880	118 =	53·5240	700 =	317·5	1,700 =	771·1	5,000 =	2,268
109 =	49·4416	119 =	53·9776	800 =	362·9	1,800 =	816·5		
110 =	49·8953	120 =	54·4312	900 =	408·2	1,900 =	861·8		

Note:

1 Cwt. = 112 lbs. = 50·8024 Kilogrammes.
1 Ton = 2,240 lbs. = 1016·048 Kilogrammes.
1 Kilogramme = 2·2046213 lbs. avoirdupois.
1 Gramme = 15·432349 Grains.

Feet and Inches Converted into Metres (*Approximate*).

Feet.		Metres.	Feet.		Metres.	Feet.		Metres.	Feet.		Metres.
0″	=	..	7′ 6″	=	2·2859	15′ 0″	=	4·5718	22′ 6″	=	6·8577
3″	=	0·0762	9″	=	2·3621	3″	=	4·6479	9″	=	6·9339
6″	=	0·1524	8′ 0″	=	2·4383	6″	=	4·7242	23′ 0″	=	7·0101
9″	=	0·2286	3″	=	2·5144	9″	=	4·8004	3″	=	7·0862
1′ 0″	=	0·3047	6″	=	2·5907	16′ 0″	=	4·8766	6″	=	7·1625
3″	=	0·3808	9″	=	2·6669	3″	=	4·9527	9″	=	7·2387
6″	=	0·4571	9′ 0″	=	2·7431	6″	=	5·0290	24′ 0″	=	7·3149
9″	=	0·5333	3″	=	2·8192	9″	=	5·1052	3″	=	7·3910
2′ 0″	=	0·6095	6″	=	2·8955	17′ 0″	=	5·1814	6″	=	7·4673
3″	=	0·6856	9″	=	2·9717	3″	=	5·2575	9″	=	7·5435
6″	=	0·7619	10′ 0″	=	3·0479	6″	=	5·3338	25′ 0″	=	7·6197
9″	=	0·8381	3″	=	3·1240	9″	=	5·4100	3″	=	7·6958
3′ 0″	=	0·9143	6″	=	3·2003	18′ 0″	=	5·4862	6″	=	7·7721
3″	=	0·9904	9″	=	3·2765	3″	=	5·5623	9″	=	7·8483
6″	=	1·0667	11′ 0″	=	3·3526	6″	=	5·6386	26′ 0″	=	7·9245
9″	=	1·1429	3″	=	3·4287	9″	=	5·7148	3″	=	8·0006
4′ 0″	=	1·2191	6″	=	3·5050	19′ 0″	=	5·7910	6″	=	8·0769
3″	=	1·2952	9″	=	3·5812	3″	=	5·8671	9″	=	8·1531
6″	=	1·3715	12′ 0″	=	3·6574	6″	=	5·9434	27′ 0″	=	8·2293
9″	=	1·4477	3″	=	3·7335	9″	=	6·0196	3″	=	8·3054
5′ 0″	=	1·5239	6″	=	3·8098	20′ 0″	=	6·0958	6″	=	8·3817
3″	=	1·6000	9″	=	3·8860	3″	=	6·1719	9″	=	8·4579
6″	=	1·6763	13′ 0″	=	3·9622	6″	=	6·2482	28′ 0″	=	8·5341
9″	=	1·7525	3″	=	4·0383	9″	=	6·3244	3″	=	8·6102
6′ 0″	=	1·8287	6″	=	4·1146	21′ 0″	=	6·4005	6″	=	8·6863
3″	=	1·9048	9″	=	4·1908	3″	=	6·4766	9″	=	8·7627
6″	=	1·9811	14′ 0″	=	4·2670	6″	=	6·5529	29′ 0″	=	8·8389
9″	=	2·0573	3″	=	4·3431	9″	=	6·6291	3″	=	8·9150
7′ 0″	=	2·1335	6″	=	4·4194	22′ 0″	=	6·7053	6″	=	8·9913
3″	=	2·2096	9″	=	4·4956	3″	=	6·7814	9″	=	0·0675

MULTIPLIERS.

	Metres into Feet.	Feet into Metres.	Millimetres into Inches.	Inches into Millimetres.	
1	3·2809	0·3048	·03937	25·400	1
2	6·5617	0·6096	·07874	50·800	2
3	9·8426	0·9144	·11811	76·199	3
4	13·1235	1·2192	·15748	101·599	4
5	16·4043	1·5240	·19685	126·999	5
6	19·6852	1·8288	·23622	152·399	6
7	22·9661	2·1336	·27559	177·798	7
8	26·2470	2·4384	·31496	203·198	8
9	29·5278	2·7432	·35433	228·598	9
10	32·8087	3·0480	·39370	253·998	10

	Square Metres into Square Feet.	Square Feet into Square Metres.	Square Millimetres into Square Inches.	Square Inches into Square Millimetres.	
1	10·764	·0929	·0015500	645·15	1
2	21·528	·1858	·0031001	1,290·30	2
3	32·292	·2787	·0046501	1,935·44	3
4	43·056	·3716	·0062001	2,580·59	4
5	53·821	·4645	·0077501	3,225·74	5
6	64·585	·5574	·0093002	3,870·89	6
7	75·349	·6503	·0108502	4,516·04	7
8	86·113	·7432	·0124002	5,161·18	8
9	96·877	·8361	·0139503	5,806·33	9
10	107·641	·9290	·0155003	6,451·48	10

	Cubic Metres into Cubic Feet.	Cubic Feet into Cubic Metres.	Cubic Millimetres into Cubic Inches	Cubic Inches into Cubic Millimetres.	
1	35·316	·028316	·00006103	16,387	1
2	70·631	·056632	·00012205	32,773	2
3	105·947	·084948	·00018308	49,160	3
4	141,262	·113264	·00024410	65,546	4
5	176·578	·141581	·00030513	81,933	5
6	211·894	·169897	·00036615	98,320	6
7	247·209	·198213	·00042718	114,706	7
8	282·525	·226529	·00048820	131,092	8
9	317·840	·254845	·00054923	147,480	9
10	353·156	·283161	·00061025	163,866	10

Measures.

	Grammes into Grains.	Grains into Grammes.	Kilogrammes into Lbs.	Lbs. into Kilogrammes.	
1	15·4323	·06480	2 2046	0·4536	1
2	30·8647	·12960	4·4092	0 9072	2
3	46·2970	·19440	6·6139	1 3608	3
4	61·7294	·25920	8·8185	1 8144	4
5	77·1617	·32399	11·0231	2·2680	5
6	92·5941	·38879	13·2277	2 7216	6
7	108·0264	·45359	15·4323	3 1751	7
8	123·4588	·51839	17·6370	3 6287	8
9	138·8911	·58319	19·8416	4 0823	9
10	154 3235	·64799	22·0462	4 5359	10

	Tonneaux into Tons.	Tons into Tonneaux.	Litres into Gallons	Gallons into Litres	
1	0·9842	1 0160	0 2202	4·541	1
2	1·9684	2 0321	0 4404	9·082	2
3	2·9526	3·0481	0 6606	13·623	3
4	3·9368	4·0642	0 8809	18·164	4
5	4·9210	5·0802	1 1011	22·705	5
6	5·9052	6·0963	1 3213	27·246	6
7	6·8894	7·1123	1 5415	31·787	7
8	7·8736	8·1284	1 7617	36·328	8
9	8·8579	9·1444	1·9819	40·869	9
10	9·8421	10 1605	2 20215	45·410	10

	Kilogram-metres into Foot-Lbs.	Foot-Lbs. into Kilogram-metres.	Kilogrammes on the Sq. Millimetre into Lbs. on the Sq. Inch.	Lbs. on the Sq. Inch into Kilogrammes on the Sq. Millimetre.	
1	7·233	0·13825	1,422	·000703	1
2	14·466	0·27651	2,845	·001406	2
3	21·699	0·41476	4,267	·002109	3
4	28·932	0·55302	5,689	·002812	4
5	36·165	0·69127	7,111	·003515	5
6	43·398	0·82952	8,531	·004219	6
7	50·632	0·96778	9,956	·004922	7
8	57·865	1·10603	11,378	·005625	8
9	65·098	1·24429	12,801	·006328	9
10	72·331	1·38254	14,223	·007031	10

MEASURES—*Contd.*

	Kilometres into Miles.	Miles into Kilometres.	Hectares into Acres.	Acres into Hectares.	
1	0·6214	1·6093	2·471	0·4047	1
2	1·2428	3·2186	4·942	0·8094	2
3	1·8641	4·8280	7·413	1·2140	3
4	2·4855	6·4373	9·884	1·6187	4
5	3·1069	8·0467	12·356	2·0234	5
6	3·7283	9·6560	14·827	2·4281	6
7	4·3496	11·2653	17·298	2·8328	7
8	4·9710	12·8747	19·769	3·2375	8
9	5·5924	14·4840	22·240	3·6421	9
10	6·2138	16·0933	24·711	4·0468	10

VELOCITIES.

	Miles per Hour into Feet per Second.	Feet per Second into Miles per Hour.	Knots into Feet per Second.	Feet per Second into Knots.	
1	1·467	0·682	1	0·592	1
2	2·933	1·364	3	1·185	2
3	4·400	2·045	5	1·777	3
4	5·867	2·727	6	2·370	4
5	7·333	3·409	8	2·962	5
6	8·800	4·091	10	3·555	6
7	10·267	4·773	11	4·147	7
8	11·733	5·455	13	4·740	8
9	13·200	6·136	15	5 332	9
10	14·667	6·818	16	5·925	10

Millimetres into Decimals and Inches.				Decimals of an Inch and Inches into Millimetres.					
Mm.	Inches.	Millimetres.	Inches.	Ins.	Millimetres.	Inches.	Millimetres.	Ins.	Millimetres.
1	·0394	20	3·7874	·01	·25	·30	7·62	5	127·0
2	·0787	30	1·1811	·02	·51	·40	10·2	6	152·4
3	·1181	40	1·5748	·03	·76	·50	12·7	7	177·8
4	·1575	50	1·9685	·04	1·02	·60	15·2	8	203·2
5	·1968	60	2·3622	·05	1·27	·70	17·8	9	228·6
6	·2362	70	2·7559	·06	1·52	·80	20·3	10	254·0
7	·2756	80	3·1496	·07	1·78	·90	22·9	11	279·4
8	·3150	90	3·5433	·08	2·03	1·00	25·4	12	304·8
9	·3543	100	3·9370	·09	2·29	2·00	50·8		
10	·3937	= 1 Decimetre.		·10	2·54	3·00	76·2	= 1 Foot.	
				·20	5·08	4·00	101·6		

Table of Degrees Centigrade Equivalent to Degrees Fahrenheit.

Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.
*1 =	−17·2	*31 =	−0·5	61 =	16·1	91 =	32·7
2 =	−16·6	32 =	0·0	62 =	16·6	92 =	33·3
3 =	−16·1	33 =	0·5	63 =	17·2	93 =	33·8
4 =	−15·5	34 =	1·1	64 =	17·7	94 =	34·4
5 =	−15·0	35 =	1·6	65 =	18·3	95 =	35·0
6 =	−14·4	26 =	2·2	66 =	18·8	96 =	35·5
7 =	−13·8	37 =	2·7	67 =	19·4	97 =	36·1
8 =	−13·3	38 =	3·3	68 =	20·0	98 =	36·6
9 =	−12·7	39 =	3·8	69 =	20·5	99 =	37·2
10 =	−12·2	40 =	4·4	70 =	21·1	100 =	37·7
11 =	−11·6	41 =	5·0	71 =	21·6	150 =	65·5
12 =	−11·1	42 =	5·5	72 =	22·2	200 =	93·3
13 =	−10·5	43 =	6·1	73 =	22·7	250	121·1
14 =	−10·0	44 =	6·6	74 =	23·3	300 =	148·8
15 =	− 9·4	45 =	7·2	75 =	23·8	400	204·4
16 =	− 8·8	46 =	7·7	76 =	24·4	500 =	260·0
17 =	− 8·3	47 =	8·3	77 =	25·0	600 =	315·5
18 =	− 7·7	48 =	8·8	78 =	25·5	700 =	371·1
19 =	− 7·2	49 =	9·4	79 =	26·1	800 =	426·6
20 =	− 6·6	50 =	10·0	80 =	26·6	900 =	482·2
						1,000 =	537·7
21 =	− 6·1	51 =	10·5	81 =	27·2	1,500 =	815·5
22 =	− 5·5	52 =	11·1	82 =	27·7	2,000 =	1,093·3
23 =	− 5·0	53 =	11·6	83 =	28·3	2,500 =	1,371·1
24 =	− 4·4	54 =	12·2	84 =	28·4	3,000 =	1,648·8
23 =	− 3·8	55 =	12·7	85 =	29·4		
26 =	− 3·3	56 =	13·3	86 =	30·0		
27 =	− 2·7	57 =	13·8	87 =	30·5		
28 =	− 2·2	58 =	14·4	88 =	31·1		
29 =	− 1·6	59 =	15·0	89 =	31·6		
30 =	− 1·1	60 =	15·5	90 =	32·2		

Do not multiply the figures. If two or more of the Centigrade equivalents are united to make a required number 17·7° Cent. must be added for each sum combined to the original. This 17·7 is 32° × 5 ÷ 9 = 17·7, so . . . . .

900 =	482·2
250 =	121·1
200 =	93·3
150 =	65·5
1,500 =	762·1
17·7 × 3 =	53·1
	815·2

* Note.—The figures from 1 to 31 Fahr. in the Centigrade column are all minus 0·00 Cent.

Note.—To convert Fahr. into Cent. deduct 32. Multiply by 5, and then divide by 9.

How far Sounds Travel.—Noises that were heard in a balloon:

	Feet.
Man's shout (heard distinctly),	1,600
Sharp note of the mole-cricket,	2,500
Croaking of Frogs in a marsh,	3,000
Man's voice and the rolling of a cart,	3,255
Roll of drum and music of orchestra,	4,500
Crowing of cocks, note of church bells and sometimes shouting of men and women,	5,000
Report of a rifle and barking of a dog,	5,900
Noise of a railway train in motion,	8,200
Whistle of a railway engine,	10,000

CAMILLE FLAMMARION.

DO NOT

Tear the skin or break a blister, but cover the burnt or scalded parts with clean cotton-wool or other suitable material (see first aid upon this and other injuries).

Neglect to keep important documents and valuables in a well-made safe.

Store oil, methylated spirits, or other highly inflammable goods in cupboards under the stairs.

Use flexible tubing for supplying gas to boiling rings, and in every case see the only tap is at the end opposite the burner.

Allow greasy rags or other dirt and rubbish to lie about, see they are kept in iron receptacles.

Place ashes in wooden boxes or wicker waste-paper baskets.

Light a gas stove or gas ring near the inlet, but at the furthest point from the tap. The air will then be forced out and the explosive mixture expelled.

Use in a mineral oil lamp a wick that does not quite fill the wick-tube or one that has to be squeezed into it. The wick should be dried at a fire and immediately soaked with oil before placing in the tube.

Use wicks more than 10 inches in length, but see they reach the bottom of the oil-container.

Use wicks for more than 2 or 3 months.

Use a chimney that does not fit, it may fall off.

Allow a dirty burner to be used, it should be taken to pieces and cleansed once a month.

Refill a lamp when alight, or near a fire or other light.

Spill the oil: if any spilt, wipe all dry.

Light the lamp if the slit in the cone is not exactly over the wick-tube.

Allow the oil to get low, fill up each morning and keep the container well filled.

Blow down a chimney to extinguish a lamp, but across the top after the wick has been turned down to a flickering flame.

DO NOT

Use a lamp which is broken or in any way out of order, or a chimney which is cracked. Any parts loose, out of shape, or defective, should be at once repaired.

Allow a lamp to be left upon an insecure table or wall.

Carry lamps about more than is absolutely necessary.

Turn down lamps except to extinguish.

Smoke in a motor garage or near any petrol.

Leave your house for any length of time without turning the gas off at the meter.

Neglect to inspect all stores and furnace pipes, smoke vents and flues, when of iron and out of use they rust and holes are often found.

Neglect to see that all by-pass and other gas taps are turned off before the supply is shut off at the meter.

Neglect to see that all cupboards and store places are periodically cleaned.

Remove the key of the gas meter; should it be necessary, see it is hung near the meter for instant use.

Use telescopic or sliding gasaliers that require water to seal the tubes.

Allow loose or worn gas taps to remain, see the stops are in order.

Use composition pipe for gas supply.

Open windows of rooms in which there is a smell of gas until all by-pass burners and other lights are extinguished.

Neglect to send to the Gas Co. in all cases of leakage.

Try to discover an escape of gas with a light.

Forget gas is lighter than air and the upper part of the windows should be opened first.

Apply a light to burners at once if the gas should suddenly go out. It may be caused by a defect in the meter, or naphthaline in the mains, turn off all the taps and relight carefully, one at a time as the supply returns.

Neglect to instruct and practice the members of your household in what to do in case of fire.

Neglect to have posted in your house how to call the Fire Brigade.

Leave the house by a trap door on to the roof unless you know how to get down.

Bustle or cause confusion, but be prompt and calm.

Allow air or draught to reach a fire as the oxygen acts as a feeder.

Neglect to close all doors and windows after passing.

Forget that heated air ascends and that colder air is to be found near the floor and often a view can be obtained of the fire.

Jump out of a window if bed clothing or ropes are at hand that by tying together you may be able to descend.

Permit strangers to enter or assist in removing goods or some may be missing.

Remove goods before it is necessary, they may be more damaged by removal than by the fire.

Leave your own house open and unprotected while you assist your neighbour.

Neglect to have hot-water pipes and boilers examined yearly and any deposit removed.

DO NOT

Forget that a fire can be smothered (*i.e.*, the oxygen kept away) by the use of rugs, mats, carpets, blankets, towels, if thrown over the burning material and well pressed down. If damp so much the better.

Forget that wet mops, brooms and such like things can be used with advantage on small fires, and will often allow burning material otherwise out of reach to be cooled down.

Forget that the provision of small first-aid appliances tend to remind people that fires may occur and that they should take care.

Fig. 270.—There are Fools and Fools, but the Prize Fool is this one.

Use any but safety matches.

Leave matches within the reach of children.

Throw used or unused matches upon the floor (see Fig. 270).

Leave cigarettes, cigar ends, lighted tobacco lying about.

Leave a room with a fire without placing the guard in position and see that it is so fixed that the dog or cat cannot move it.

Smoke in bed.

Read in bed with *unguarded* lights.

Use swinging gas brackets, unless fitted with strong wire guards.

DO NOT

Place wax or other candles in position where they will be subject to heat and bend over.

Use flimsy glass containers for lamps.

Neglect to investigate at once every smell of fire or smoke.

Neglect to examine premises after workmen have left.

Remove lighted coals from the grate to the hearth.

Carry lighted coals from one room to another.

Leave lights near open windows, with blinds or curtains.

Place clothes near fireplace where they can be blown on to the fire.

Allow soot to accumulate above and at the back of fire grates.

Turn off the gas at the meter unless you are sure all taps are turned off and none of the by-pass burners are in use.

MISCELLANEOUS.

"Preventable fire is more than a private misfortune. It is a public dereliction. At a time like this (1919) of emergency and of manifest necessity for the conservation of national resources it is more than ever a matter of deep and pressing consequence that every means should be taken to prevent this evil."—President WOODROW WILSON.

"All fires are the same size at the start."

"Do not confound 'fire' with 'loss'. The loss is *preventable.*"

"Evils which have never been suffered are hard things to clothe with reality until it is too late, and words—even the most eloquent and persuasive—are but a poor implement for the task."—F. S. OLIVER.

"Most fires can be prevented by good house-keeping, or, in other words, cleanliness and watchfulness."

"Do not put your trust in a 'fire-proof' building—your responsibility is just as great as in a structure of readily combustible material."

"Study to prevent fires in your house and in your place of business."

"Be ready to put fires out before they become dangerous."

"Fire Prevention is largely a matter of *cleanliness* and *carefulness* in the individual—in fact—in YOU."

A small spark makes a great fire.

Three removes are as bad as a fire.

Fire is not to be quenched with Tow.

The eye of the Master does more work than both his hands.

Where much smoke is, there must be some fire.

In unremorseful clouds of rolling fire.

"That which they have done but earnest of the things which they shall do."

"The fire that wastes the mountains' mighty woods grows from one single spark."

"Even so the tongue is a little member, and boasteth great things. Behold, how great a matter a little fire kindleth!"

"And the tongue is a fire, a world of iniquity: so is the tongue among our members, that it defileth the whole body, and setteth on fire the course

of nature; and it is set on fire of hell."—*The General Epistle of St. James*, Chapter III., v. 5 and 6.

"O ye fire and heat, bless ye the Lord: praise Him, magnify Him for ever."

"O ye wells, bless ye the Lord."—*Benedicite, Omnia Opera.*

"A little fire is quickly trodden out. Which, being suffered, rivers cannot quench."—*King Henry* VI., Part 3, Act 4, Scene 8.—SHAKESPEARE.

If the design, material and workmanship be good the cost of working and repairs will be lower than with inferior goods.

No "makeshift" except under the most unavoidable circumstances should be allowed to exist for one moment in connection with Fire extinguishing machinery.

In 1912 members of the British Fire Prevention Committee visited Russia and, amongst many interesting incidents, they found at St. Petersburgh, situated upon the first floor of a Fire Station, a well equipped School for the Instruction of Fire Brigade Officers; upon entering the ground floor, used as stables, they found the harness held together with pieces of string.

CHAPTER XX.

SOME HISTORICAL FIRES.

Date.		Place.	Damage.
B.C.	70	Jerusalem.—The Temple destroyed.	
	47	Alexandria.—Library of 400,000 manuscripts destroyed.	
A.D.			
	59	Lyons.—Burned. Nero rebuilt most of it. . .	
	64	Rome.—Burned (said by the order of Nero). . .	
10 Aug.,	70	Jerusalem.—Temple burned by Roman soldiery. Enormous loss of life.	
	103	Nicomedia.—Pliny the younger reported to the Emperor Trajan that the fire could not be extinguished as the city was not furnished with engines, buckets, or any other appliances. He asked permisssion to form a company of 150 firemen. Permission was not granted on the ground that firemen were frequently guilty of breaches of the peace. . .	
27 Oct.,	446	Constantinople.—Destroyed.	
	640	Alexandria.—The Serapaeum Library of 700,000 volumes destroyed by the order of Caliph Omar, see p. 1.	
	741	York.—Destroyed.	
	754	Canterbury.—Almost totally destroyed. . . .	
	798	London.—Nearly destroyed.	
	839	London.—Destroyed by the Danes.	
	856 857	Paris.—Destroyed by the Normans. The buildings left by the fire of 856 were burned in the following year.	
	886	Paris.—All between the Ile and the City again burned by the Normans.	
	900	The Pope (John IX.) directed the church bells to be rung as a preservative from destructive fires. .	
	982	London.—A large portion of the city, including St. Paul's Cathedral.	
	1001	Clifton and Wilton. . . . — Burned by the Danes who for some years were complete masters of the Country.	
	1002	Oxford.	
	1003	Exeter.	
	1004	Norwich.	
	1006	Wallingford.	
	1009	Oxford.	
	1010	Bedford, Temsford, and Northampton.	
	1032	Oxford.	
	1064	Northampton.	
	1068	Curfew introduced by William I., see p. 3. . .	
	1086	London.—All the churches and houses from Eastgate to the Westgate, including St. Paul's, destroyed.	
	1100	Curfew as a compulsory institution abolished by Henry I.	
	1106	Venice.	
	1118	Nantes.—Greater part destroyed.	
	1136	London.—Houses between London Stone and Blackfriars, including the timber bridge over the Thames.	
	1137	Dijon.—Burned.	
	1137	York.—City almost totally destroyed. . . .	
	1184	Glastonbury.—Town and abbey destroyed. . .	

Date.	Place.	Damage.
A.D. 10 July, 1212	London.—The Church of Our Lady of the Cannons and Borough of Southwark being on fire, a great multitude of people assembled upon and crossed over the bridge to help, when through a southernly wind the buildings upon the north end caught fire and the people were trapped. Barges and boats came to the rescue, but they in turn took fire and sank. 3,000 persons are said to have been drowned. The fire extended over the greater portion of the city, and it is alleged that in all 12,000 lives were lost. This was called the great fire until 1666. . .	
1272	Norwich.—Great destruction of property and loss of life, arising out of a quarrel between the monks and the burghers. 34 persons executed for incendiarism in Sept.	
1292	Carlisle.—Destroyed.	
1299	Wiemar.	
1379	Memel.	
1405	Blon.—Destroyed.	
1420	Leipzig.—400 houses.	
1424	Weimar.	
1457	Memel.	
1457	Dort.—Cathedral and part of town.	
1463	Constantinople.—Destroyed.	
1471	London.—Suburbs of city—3 score houses—burned by riotous shipmen from Essex and Kent. . .	
1471	London.—Thomas Fawconbridge burnt the gate and 13 houses on London Bridge.	
1491	Dresden.—Destroyed.	
1505	Norwich.—718 houses burned.	
1521	O Viedo.—Partly destroyed.	
1524	Troyes.—Nearly destroyed.	
1530	Aalborg.—Nearly destroyed.	
1536	Cuzco (Peru).—Nearly destroyed.	
1540	Memel.	
1541	Aarhuus (Jutland).—Destroyed.	
1543	Komorn (Hungary).—Destroyed.	
1544	Leith.—Destroyed.	
1556	Aarhuus.	
1577	Venice.	
1598	Tiverton.—400 houses. A large number of horses and much property destroyed. 33 persons killed, .	£156,000
1612	Tiverton.—600 houses. Only the church, schools, and 30 houses remained, ...	200,000
1612	Edinburgh.—The Great Fire.	
1613	Dorchester.—Nearly destroyed. 300 houses and two churches, ...	200,000
1613	London.—Globe Theatre, Southwark, caused by ignition of the thatched roof from a wad out of a cannon used during a play, ...	
1614	Stratford-upon-Avon.—Burnt.	
1618	Weimar.	
1624	Oporto.—Nearly destroyed.	
1631	Rajmahal (Bengal).—Palace and great part of town destroyed.	
1634	Fürth.—Destroyed by Austrian Croats. . . .	
1644	Beaminster.—Destroyed.	
1652	Glasgow —One-third destroyed.	
1662	Dorchester.—Second serious damage.	
2nd to 6th Sept. 1666	London.—Great Fire. Only 6 lives lost, 13,200 houses, 400 streets, 89 churches, St. Paul's, Royal Exchange and many other large buildings utterly destroyed ; the fire laid bare an area of 436 acres, and extended from the Tower to the Temple, and from the river up to Holborn Bridge, Out of 26 wards, 15 were destroyed, ...	10,716,000

Date.	Place.	Damage.
A.D. Jan. 1672	London.—Drury Lane Theatre and 60 houses destroyed.	
1675	Northampton.—Almost destroyed.	
1676	London.—Change Alley, Cornhill Ward, 200 houses,	
1678	Memel.	
1679	Boston.—All the warehouses, 80 dwellings and vessels in the river destroyed.	
1680	Fürth.	
1683	Newmarket.—Partly destroyed.	
1684	Beaminster.—Burnt down, second time.	
1686	Landau, France.	
19 April, 1689	Copenhagen.—Opera House (wood), and the Castle of Amalienborg destroyed, 210 persons killed.	
1694	Warwick.—More than half destroyed.	
1700	Edinburgh.—The "Great Fire."	
1702	Bergen.—Greater part destroyed.	
1720	Rennes.—850 houses.	
1727	Gravesend.—Destroyed.	
1728	Copenhagen.—1,650 houses, 77 streets, 5 churches, and 5 colleges.	
1729	Constantinople.—12,000 houses and 7,000 inhabitants.	
1731	Tiverton.—300 houses.	
1736	Moscow.—2,000 houses.	
1738	Wellingborough.—800 houses.	
1743	Crediton (Devon).—450 houses.	
1744	Brest.—Magazines and stores, valued at several millions sterling.	
1749	Constantinople.—12,000 houses, and later in the year 10,000 more.	
1751	Constantinople.—4,000 houses.	
1751	Stockholm.—1,000 houses.	
1752	Moscow.—18,000 houses.	
1752	Piere (Martinique).—700 houses.	
1752	St. Petersburg.—2,000 houses.	
1753	Archangel.—900 houses.	
1756	Constantinople.—15,000 houses and 100 persons.	
1758	Pirna (Saxony).—By Prussians. 260 houses.	
1759	Stockholm.—250 houses.	
1760	Boston (U.S.).	£100,000
1760	Portsmouth.—Dockyard,	400,000
1761-5-7-9	Constantinople.—Great havoc.	
1763	Archangel.—Destroyed.	
1763	Smyrna.—2,600 houses.	
1764	Konigsberg.—Public buildings,	600,000
1762	Munich.—200 houses.	
1769	Konigsberg.—Almost destroyed.	
1770	Portsmouth.	100,000
1771	Constantinople.—Great havoc.	
1772	Smyrna.—3,000 houses, 4,000 shops,	4,000,000
1775	Abo (Finland).—200 houses, 15 mills.	
1777	Archangel.—200 houses.	
1778	New Orleans.—Seven-eighths destroyed.	
12 Nov., 1778	Saragossa (Spain).—Teatro Colisseo. 77 persons (including the Governor) killed, 52 badly injured.	
1778	Charleston (S. Carolina).	100,000
1778	Constantinople.—2,000 houses.	
1780	London.—Lord George Gordon riots (2 June). Fired public buildings, Newgate, Clerkenwell, the Fleet, King's Bench, Borough Clink and Bridewell prisons, liberated 300 prisoners. 500 persons killed and wounded, 36 incendiary fires during the night.	
1780	St. Petersburg.—11,000 houses.	
1781	Beaminster.—One-third of town. Third time.	
1782	Constantinople.—In February 600 houses, in June 7,000 houses, August 10,000 houses, 30 mosques, and 100 cornmills.	

Date.	Place.	Damage.
A.D.		
1783	London.—Aldersgate Street, 40 houses,	£100,000
1784	Constantinople.—10,000 houses.	
1784	Brest.—Stores,	1,000,000
1784	Rokitzan (Bohemia).—Totally,	500,000
1786	Tobolsk (Russia).—Nearly destroyed.	
1787	Ruppen (Brandenburg).—600 houses.	
1788	Mitan (Turkestan).—Nearly destroyed.	
17 June, 1789	London.—The Opera House, later Her Majesty's Theatre, destroyed.	
1790	Carlscrona (Sweden).—1,087 houses, 2 churches, and all the warehouses.	
1791	Constantinople.—Between March and July, 32,000 houses.	
1792	Constantinople.—7,000 houses.	
1793	Archangel.	
1794	Copenhagen.—Royal Palace and contents, 100 persons,	4,500,000
1794	Boston (U.S.).	200,000
1794	London.—630 houses and East India Warehouse at Wapping,	1,000,000
1795	Constantinople.—30,000 houses.	
17 Sept. 1794	London.—Astley's Amphitheatre and many buildings.	
1795	Copenhagen.—The Arsenal, the Admiralty, 50 streets, and 1,563 houses. One-fourth of city.	
1795	Montego Bay (Jamaica),	400,000
1796	Portsmouth.—Serious damage.	
1796	St. Petersburg.—Naval stores and 100 vessels.	
1796	Barbadoes.—Two conflagrations causing enormous damage.	
1796	Smyrna.—4,000 shops, 2 large mosques, 2 public baths, all the magazines and provisions, value 10,000,000 crowns.	
1797	Scutari (Constantinople.—Town of 3,000 houses destroyed).	
1799	Pera.—1,300 houses and many fine buildings.	
1799	London.—The King's Bench and 50 houses.	
1799	Manilla (East Indies).—Vast storehouses.	
1800	London.—3 West India Warehouses,	300,000
1801	Brody (Galicia).—1,500 houses.	
1802	Gothenburg.—178 houses.	
1802	Liverpool.—St. George's Docks,	1,000,000
1802	Portsmouth (U.S.).—102 buildings.	
1802	London.—Woolwich Arsenal storehouses,	200,000
1 Sept. 1803	London.—Astley's Amphitheatre and 40 houses.	
1803	Madras.—1,000 houses,	600,000
1803	Posen (Germany).—283 houses.	
1805	Island of St. Thomas.—900 warehouses,	6,000,000
1805	London.—Woolwich Arsenal. Great fire.	
1808	Isle of Trinidad.—Spanish town destroyed.	
1808	London.—Convent Garden Theatre destroyed.	
24 Feb. 1809	London.—Drury Lane Theatre destroyed.	
1811	London.—Half Bury Street, St. Mary Axe.	
1811	Tyrol.—Forest fires, 64 villages and hamlets.	
14 Sept. 1812	Moscow.—The Russians fired the city to eject the army of Napoleon. The fire continued 5 days. Nine-tenths of the city was destroyed, 30,800 houses.	
1812	Riga.—Nearly destroyed.	
1813	Portsmouth (U.S.).—397 buildings.	
1813	London.—Woolwich Arsenal gunpowder explosion.	
1813	London.—Woolwich Arsenal hemp store.	
1814	London —Woolwich Arsenal gunpowder explosion.	
1814	London.—Custom House, public records and many warehouses.	
1815	Quebec.—Public stores and warehouses,	260,000
16 Aug. 1816	Constantinople.—12,000 houses and 3,000 shops in the best quarter.	

DATE.	PLACE.	DAMAGE.
A.D. 1818	Salzburg (Austria).—Partly.	
13 Aug. 1818	Constantinople.—4,000 houses.	
1820	Savannah (U.S.).—463 buildings.	
1820	London.—Rotherhithe,	£80,000
1822	London.—Mile End,	200,000
1822	London.—Smithfield,	100,000
1822	Canton.—Nearly destroyed.	
1825	New Brunswick.—A tract of 4,000,000 acres, more than 100 miles in length, was burned over. It included many towns, 160 persons killed and 875 head of cattle. 590 buildings in the towns of Newcastle, Chatham, and Douglastown destroyed,	60,000
1826	Constantinople.—6,000 houses.	
1827	Abo (Finland).—780 houses.	
1827	Sheerness.—50 houses and much property.	
1828	Havana.—350 houses, 2,000 persons homeless.	
2 May, 1829	York.—Cathedral Choir burnt out and Nave damaged.	
1830	London.—Astley's Amphitheatre.	
1832	London.—Custom House,	400,000
26 Mar., 1833	Manilla.—10,000 huts, 50 lives, 30,000 homeless.	
1834	London.—Two Houses of Parliament.	
1834	Tula (Mexico).—Nearly destroyed.	
1835	New York.—674 warehouses, public buildings and stores. 52 acres of the business part of the city,	4,000,000
14 Feb., 1835	St. Petersburg.—Lehmann's Theatre. Nearly 800 persons killed and injured.	
1837	St. Petersburg.—The Winter Palace entirely destroyed.	
13 Jan., 1837	St. John's (New Brunswick).—115 houses, being nearly all the business part of the city,	1,000,000
10 Jan., 1838	London.—Royal Exchange.	
27 April, 1838	Charleston (U.S.).—Half of the city, 1,158 buildings,	600,000
1840	Devonport.—Dockyard. "Talavera" of 74 guns, "Imogene" frigate of 28 guns, stores, the naval museum with valuable relics,	200,000
8 June, 1841	London.—Astley's Amphitheatre and 23 houses destroyed.	
1841	Smyrna.—12,000 houses.	
30 Oct., 1841	London.—Tower armoury, 280,000 stand of arms and interesting relics.	
4 May, 1842	Hamburg.—Fire lasted 3 days, churches, public buildings, and 2,000 houses,	7,000,000
23 Sept., 1842	Liverpool.—Paisley and Formby Streets. Many lives,	700,000
1843	Port Republican (Hayti).—Nearly one-third of town.	
19 July, 1843	Miskolcz (Hungary).—Theatre and half the town.	
1845	Quebec.—1,650 houses, and a month later 1,365 houses.	
11 April, 1845	Pittsburg (U.S.).—20 acres of city including 1,100 buildings,	2,000,000
20 July, 1845	New York.—300 buildings in business part, 35 persons killed,	15,000,000
18 Aug., 1845	London.—Warehouses, Aldermanbury,	250,000
9 June, 1846	St. John's (Newfoundland).—Nearly the whole town,	1,000,000
12 June, 1846	Quebec.—Royal Theatre. 200 persons killed and many injured.	
1846	Nantucket (U.S.).—Almost destroyed.	
1848	Albany.—One-third of city, 37 acres, 600 houses,	600,000
1848	Constantinople.—500 houses and 2,000 shops,	3,000,000
1848	Orel (Russia).—Large part destroyed.	
17 May, 1849	St. Louis (U.S.).—15 blocks of the city and 23 steamers at the wharves.	
1850	Cracow (Austria).—Large part of town.	
7 June, 1850	Montreal.—200 houses.	
9 July, 1850	Philadelphia.—400 buildings.	
19 Sept., 1850	London.—Corn Exchange, Mark Lane and Warehouses.	200,000
3 May, 1851	San Francisco.—Three-fourths of city, number of lives and 2,500 houses,	2,000,000

DATE.	PLACE.	DAMAGE.
A.D.		
4 May, 1851	St. Louis.—2,500 buildings,	£2,200,000
1851	Washington.—Part of Capitol and whole of Congressional Library.	
1851	London.—Duke Street, London Bridge,	60,000
1851	London.—Hop and 3 other warehouses,	150,000
22 June, 1851	San Francisco.—500 buildings.	600,000
June, 1851	Archangel.—Municipal Theatre and many public and private buildings.	
8 July, 1852	Montreal.—2,000 houses, 15,000 persons homeless,	1,000,000
12 Nov., 1852	Sacramento City (California).—Most of city, 2,500 buildings.	
1853	London.—Gutta Percha Works, City Road,	100,000
1853	London.—Scott Russell's works,	100,000
1853	London.—Bread Street,	80,000
1853	New York.—Printing Works,	275,000
1854	Memel.	
1854	London.—Broadwood's pianoforte works,	100,000
5 Oct., 1854	Gateshead-on-Tyne.—Bonded warehouses, an explosion heard 20 miles away, fire extended to Newcastle. 50 lives lost and many injured,	1,000,000
1855	London.—Railway works, New Cross,	54,000
1855	London.—Saw-mills and wood yards, Blackfriars Road	150,000
1855	London.—The "Etna," steam floating battery, building for the British Government and ready for launching, cause unknown,	60,000
5 Mar., 1856	London.—Covent Garden Theatre.	
7 June, 1857	Leghorn.—Teatro Legli Acquidotti. 43 persons killed, 134 injured.	
1857	Chicago.—14 lives,	100,000
13 April, 1858	Christiania.—Large part of city,	250,000
13 Nov., 1858	Valparaiso.	600,000
1859	Brody (Austria).—1,000 houses.	
16 May, 1859	Key West (U.S.).—Buildings over 20 acres,	550,000
17 May, 1859	St. Louis (U.S.).	
15 Sept., 1859	Chicago,	100,000
13 Feb., 1860	Barbadoes.—Commissariat and other buildings,	500,000
17 Aug., 1860	London.—West Kent and Hibernia Wharves,	200,000
1861	Glarus (Switzerland).—500 houses.	
1861	Mendoza (Argentina).—Great fire followed an earthquake which had destroyed 10,000 people.	
22 June, 1861	London.—Tooley Street Wharves. Supt. Braidwood killed,	2,000,000
12 Dec., 1861	Charleston (U.S.).—Considerable portion of city,	2,000,000
1862	Marseilles.	
10 June, 1862	St. Petersburg,	1,000,000
1862	Valparaiso.—Devastated.	
1862	Troy (New York).—Nearly destroyed.	
1863	Santiago.—2,000 persons, mostly women and children, perished in Jesuit Church.	
1863	London.—Portland Bazaar,	70,000
1864	London.—Pimlico Wheel works,	180,000
1864	Novgorod (Russia).—Very severe damage.	
1864	London.—Saville House, Leicester Square,	40,000
1864	London.—Supposed fireproof carpet warehouse in Gresham Street, totally destroyed,	180,000
3 April, 1864	Georgetown (Demerara).—Nearly half the town,	600,000
5 July, 1864	Georgetown (Demerara).—The remaining portion of city,	300,000
31 Jan., 1865	London.—Surrey Theatre and neighbouring houses.	
1865	Quebec.—100 houses in a street half a mile long.	
23 Feb., 1865	Port-au-Prince (Hayti).—600 houses.	
1865	Manilla.—2 fires. 600 houses and huts.	
1865	Carlstad (Sweden).—Cathedral, Hospital, the whole town except the Bishop's residence. 5,000 people homeless.	

Date.	Place.	Damage.
A.D. 1865	Constantinople.—Public buildings, 2,800 houses, over 22,000 people homeless.	
1 Jan., 1866	London.—St. Katherine's Docks, ...	£200,000
23 May, 1866	Manchester.—Goods Railway Stations, . . .	300,000
4 July, 1866	Portland (U.S.).—200 acres, being nearly all the business portion of the city. 8 churches, the banks, and newspaper offices, 2,000 families homeless. 50 buildings blown up to stop progress of fire, .	2,000,000
10 Aug., 1866	Chicago, ...	100,000
19 Aug., 1866	Jersey City (New York).—50,000 barrels petroleum, .	400,000
16 Oct., 1866	Quebec.—2,500 houses, 17 churches, 18,000 people homeless in the French quarter, . . .	600,000
18 Nov., 1866	Chicago, ...	100,000
30 Nov., 1866	Yokohama (Japan).—50 acres, two-thirds of the town and one-sixth of the foreign settlement, . .	500,000
April, 1867	St. Louis. (U.S.)—The Linnell Hotel, 530 rooms, .	300,000
6 Dec., 1867	London.—Her Majesty's Theatre and several adjoining houses, ...	
1868	Albany (New York).	600,000
1868	Charleston (U.S.), ...	600,000
1869	Bordeaux.—30 vessels destroyed.	
4 Aug., 1869	Philadelphia (U.S.).—25,000 barrels whisky, . .	700,000
27 April, 1870	Egypt.—Viceroy's Palace at Ramle, . . .	300,000
5 June, 1870	Constantinople.—The suburb of Pera, over 7,000 buildings, including the foreign legations, . .	5,000,000
4 Sept., 1870	Chicago.—The fine square " Drake Block," . .	500,000
1871	Paris.—Communist devastations, ...	32,000,000
9 Oct., 1871	Chicago.—This great fire covered an area of nearly 4 square miles. 250 lives lost, 98,500 homeless, 17,430 buildings, ...	33,000,000
Oct., 1871	Wisconsin and Michigan (U.S.).—Forest and Prairie. 1,000 lives lost, 15,000 homeless, . . .	600,000
1872	Canterbury.—Cathedral roof burned. . . .	
1872	Tokio.—Fire covered 6 square miles, 20,000 homeless.	
2 Nov., 1872	Boston (U.S.).—748 houses, the largest business blocks in the city, the whole covering an area of 65 acres,	14,000,000
9 June, 1873	London.—Alexandra Palace destroyed, . . .	500,000
July, 1873	Portland (U.S.).—366 buildings, ...	375,000
1873	Tokio.—10,000 houses.	
Sept., 1873	Havana (Cuba).—The Plaza Vapor, 2,500 persons homeless, ...	600,000
12 Feb., 1874	London.—Pimlico Pantechnicon, ...	1,850,000
1874	Liverpool.—Landing stage destroyed.	
14 July, 1874	Chicago.—New Post Office, 5 hotels, 4 chapels, 2 theatres, etc., extending over 60 acres, . .	1,000,000
Sept., 1874	Meiningen (Germany).—Nearly half the town, . .	450,000
11 Feb., 1875	Port-au-Prince (Hayti).—500 houses, one-quarter of the town, ...	400,000
28 April, 1875	Oshkosh (U.S.).—400 buildings, ...	500,000
20 May, 1875	Oskeola (U.S.), ...	400,000
26 Oct., 1875	Virginia City (U.S.).—City mine machinery, . .	1,500,000
27 Oct., 1875	Iquiqui (Peru).—Three-quarters of city, . . .	1,000,000
12 Nov., 1875	Glasgow.—Newhall Cotton Factory, ...	300,000
15 June, 1875	London.—Brook's Wharf, Thames Street, . . .	200,000
8 Feb., 1876	New York.—Broadway and Crosby Street, . .	350,000
18 June, 1876	St. John's (Quebec).—Richelieu and Champlain Streets,	500,000
5 Dec., 1876	Brooklyn (U.S.).—Conway's Theatre. 283 persons killed, large number injured.	
20 June, 1877	St. John's (New Brunswick).—Two-thirds of city, 260 acres, 37 streets and squares, 1,650 dwellings. 18 lives lost, ...	2,500,000
23 Nov., 1877	Manchester.—Goods warehouse of L. & N.W. Railway,	250,000
26 Mar., 1878	London.—Elephant and Castle Theatre and adjoining houses.	
10 April, 1878	Edinburgh.—Nelsons, Printers, Hope Park, . .	200,000

Date.	Place.	Damage.
A.D.		
15 Jan., 1879	New York.—Broadway, Grand and Crosby Streets, .	£500,000
11 Jan., 1879	Birmingham.—The free reference Shakespeare, Staunton and Cervantes Libraries, all burned. .	
9 Mar., 1879	Nevada (U.S.).—Business part of the town of Rena. 5 persons perished, ...	200,000
22 July, 1879	Irkutsk (Siberia).—17,000 people homeless, . .	4,500,000
1 Aug., 1879	Hamilton (Ontario).—John and King Streets destroyed,	200,000
15 Sept., 1879	London.—Bromley-by-Bow. Distillery, . . .	200,000
27 Dec., 1879	Boston (U.S.).—Part of site of the great fire of 1872,	200,000
28 Dec., 1879	Boston (U.S.).—In Devonshire and Federal Streets, .	500,000
8 June, 1881	Quebec.—602 houses burned. 1,211 families homeless,	400,000
7 July, 1881	Cincinnati.—Occurred in the furniture district, .	200,000
23 Mar., 1881	Nice.—Municipal Theatre. 150 to 200 persons burnt, and many injured.	
10 Sept., 1881	London.—Cheapside and Bread Street, . . .	200,000
27 Sept., 1881	Moscow (Russia).—20 warehouses destroyed, . .	400,000
26 Aug., 1881	Chicago.—Stock yard and pork packing establishment,	200,000
8 Dec., 1881	Vienna.—Ring Theatre. 449 persons killed and many injured, ...	
31 Jan., 1882	New York.—In Park Row, destroying several newspaper offices, ...	200,000
17 Feb., 1882	Massachusetts.—Leather store, 49 Washington Street, Haverhill, ...	475,000
5 May, 1882	Wisconsin (U.S.).—Timber yard at Racine, . .	200,000
19 May, 1882	Colorado (U.S.).—Leadville. Chief hotels and other buildings, ...	2,000,000
1 June, 1882	Montevideo.—The Theatre. 21 persons killed and 103 badly injured.	
23 June, 1882	Lawrence, Mass. (U.S.).—Pacific Mills stores in Broadway, ...	200,000
25 Sept., 1882	Philadelphia.—The sugar refinery totally destroyed, .	200,000
23 Oct., 1882	St. Petersburg.—At the Gromoa timber yards, . .	250,000
7 Dec., 1882	London.—Alhambra Theatre. 1 killed, 5 injured, .	
8 Dec., 1882	London.—Wood Street, Foster Porter, etc., . .	1,500,000
11 Dec., 1882	Kingston (Jamaica).—Wharves and houses. Hundreds homeless, ...	6,000,000
7 Jan., 1883	Moscow.—Buffo Theatre. 300 lives lost. . . .	
17 April, 1883	London.—Rose and Newgate Streets, . . .	300,000
11 May, 1883	Jersey City (New York).—The Standard Oil Works struck by lightning, ...	300,000
16 June, 1883	Sunderland.—Victoria Hall. 183 children killed on a staircase. Fire panic, ...	
July, 1883	Hadjin.—Nearly half the town, ...	300,000
2 Sept., 1883	Vienna.—Timber yard in Rossau, ...	1,000,000
3 Oct., 1883	Philadelphia.—The Pittsburg Exposition building destroyed, ...	200,000
26 Aug., 1883	Katamotomura (Japan).—Theatre. 75 killed, 100 badly injured.	
3 Nov., 1883	Glasgow —Buchanan Street, ...	250,000
26 April, 1884	London.—Bayswater, Whiteley's. Third fire, . .	500,000
17 April, 1885	Richmond (U.S.).—Wooden Circus. 100 persons suffocated, and great many injured. 50 horses burnt. .	
2 May, 1885	London.—Knightsbridge, Japanese Exhibition, Humphrey's Hall.	
15 Sept., 1885	Barrow-in-Furness.—Shipbuilding yard, . . .	250,000
25 May, 1887	Paris.—Opera Comique. 115 persons killed and 60 badly injured.	
27 May, 1887	Neschin.—Circus Nikitin. About 300 people injured. .	
6 Aug., 1887	London.—Bayswater, Whiteley's. Seventh Fire, .	200,000
5 Sept., 1887	Exeter.—New Theatre Royal. 86 killed, over 100 injured.	
20 Mar., 1888	Oporto.—Théâtre Baquet. 170 people suffocated and many severely injured.	
1 April, 1888	Celaya (Mexico).—The Arena. 30 persons killed and 60 injured.	

DATE.	PLACE.	DAMAGE.
A.D. April, 1888	Kjoeng (Corea).—National Theatre. 650 persons burnt or suffocated.	
25 June, 1888	Sundsvall (Sweden),	£1,500,000
19 Sept., 1888	Brisbane,	400,000
27 Nov., 1889	Boston (U.S.).—20 lives lost,	2,000,000
25 Dec., 1889	London.—Charterhouse Street.	
30 Dec., 1890	London.—Great Fire, Queen Victoria Street.	
27 April, 1892	Philadelphia.—Grand Central Theatre and several adjoining houses and an hotel. 14 killed, 70 injured.	
8 July, 1892	St. John's (Newfoundland).—Long's Hill,	3,000,000
18 July, 1893	London.—St. Mary Axe,	280,000
5 Aug., 1893	Liverpool.—Canada Dock, Timber Yards,	1,000,000
15 Nov., 1893	London.—Old Bailey and Fleet Street.	
21 Dec., 1893	Sheffield.	
4 May, 1894	Dublin.	
21 June, 1894	London.—Tabernacle St., Finsbury.	
5 July, 1894	Chicago.—Six large buildings,	980,000
13 Sept., 1894	London.—Bermondsey, Leather Market	
10 Nov., 1894	London.—Minories.	
17 Nov., 1894	Nottingham.	
6 Jan., 1895	Toronto (Canada).—Globe building,	250,000
10 Jan., 1895	Toronto.	
8 Feb., 1895	London.—S.W. India Docks.	
4 Mar., 1895	Port of Spain (Trinidad).	
13 Mar., 1895	Toronto.	
17 May, 1895	London.—Bermondsey, Leather Market.	
5 Sept., 1895	Salonica.—Over 250 acres,	200,000
28 Jan., 1896	London.—Cambridge Music Hall.	
10 June, 1896	London.—Finsbury, Charlotte and Leonard Streets.	
30 Sept., 1896	Aberdeen.—People's Palace of Varieties. 5 killed, 30 injured.	
5 Oct., 1896	Quayaquil (Ecuador),	4,320,000
30 Nov., 1896	Bradford.—Warehouses, Foster Square,	300,000
16 Jan., 1897	Glasgow.—Anderston Quay.	
4 May, 1897	Paris.—Charity Bazaar. 124 killed and many injured.	
17 Oct., 1897	Windsor (Nova Scotia).—Occurred in a stable on one of the Wharves,	300,000
19 Nov., 1897	London.—Cripplegate, 122 Warehouses,	1,250,000
20 Nov., 1897	Melbourne.—Flinders Lane,	1,000,000
9 Feb., 1898	Pittsburg (Pennsylvania).—Cold storage warehouse,	330,000
20 April, 1898	London.—Spurgeon's Tabernacle.	
25 April, 1898	Glasgow.—Dunlop Street.	
12 May, 1898	Chicago (Illinois).—Armour's grain elevator,	240,000
18 July, 1898	Sunderland.	
8 Aug., 1898	Switzerland (Chevres near Geneva).—Electric Light station,	200,000
26 Aug., 1898	France (Landes).—Pine Forest,	400,000
31 Aug., 1898	Bristol.—Colston Assembly Hall and Factory,	65,000
10 Sept., 1898	New Westminster (British Columbia).—In a large wooden warehouse,	400,000
10 Sept., 1898	Jerome (Arizona),	200,000
23 Nov., 1898	San Francisco.—Baldwin Hotel, theatre and stores,	300,000
4 Dec., 1898	New York.—Mercantile establishment and the *Home* Life Insurance Co.,	200,000
20 Dec., 1898	Montreal.—Three wholesale dry goods store,	200,000
Feb., 1900	Newark (New Jersey).—Department store, etc.,	200,000
April, 1900	Pittsburg (Pennsylvania).—Department store,	240,000
27 April, 1900	Ottawa (Hull, Ontario),	1,500,000
June, 1900	Hoboken (New Jersey).—Dock property, merchandise and steamers,	1,000,000
June, 1900	Bloomington (Illinois).—Business portion of the town,	370,000
July, 1900	Constable Hook (New Jersey).—Oil Works,	270,000
July, 1900	Prescott (Arizona).—Business portion of the town,	200,000
Aug., 1900	Ashland (Wisconsin).—Timber yards,	200,000
Sept., 1900	Santa Rosa (California).—Forest Fires,	250,000

Date.	Place.	Damage.
A.D.		
23 Jan., 1901	Montreal.—Board of Trade buildings, ...	£500,000
Jan., 1901	New York.—Messrs. Wicks & Co., cigar box factory,	300,000
3 May, 1901	Jacksonville (Florida).—Conflagration, ...	2,000,000
5 June, 1901	Antwerp.—L'Entrepot Royal, ...	1,000,000
July, 1901	Wichita (Kansas).—Dold Packing Co., ...	200,000
10 July, 1901	Sydney.—Messrs. Anthony Hordern & Sons, merchants,	400,000
12 July, 1901	Lindon.—West India Docks, ...	200,000
Feb., 1902	Waterbury (Connecticut).—Conflagration, . .	300,000
Feb., 1902	Paterson (New Jersey).—Conflagration, . . .	900,000
27 June, 1902	Cape Town (South Africa).—City Chambers. Destruction of 8 buildings, ...	250,000
11 Sept., 1902	London.—Harrow Road, Dixon's depository, . .	200,000
Feb., 1903	Rock Island (Illinois).—Arsenal, shops and storehouse,	353,000
Feb., 1903	Cincinnatti (Ohio).—Theatre block, stores and offices,.	258,000
1 July, 1903	Eton College.—3 boys burned in a school house, windows barred, ...	
10 Aug., 1903	Paris.—Metropolitan Railway Trains. 85 deaths in tunnel.	
Nov., 1903	Troy (New York).—Pier and stores, ...	200,000
30 Dec., 1903	Chicago.—Iroquois Theatre. 571 lives lost. . .	
Jan., 1904	Shelby (Ohio).—Shelby Steel Tube warehouses, . .	300,000
Feb., 1904	Baltimore (Md.).—General conflagration. 80 city blocks, 140 acres, ...	10,000,000
Feb., 1904	Rochester (N.Y.).—Seven business buildings, . .	600,000
19 April, 1904	Toronto (Ont.).—120 mercantile buildings, . .	1,500,000
May, 1904	Yazoo (Miss.) —259 buildings, ...	300,000
May, 1904	Jersey City (N.J.).—Steamship wharf property, .	200,000
June, 1904	Poeria (Illinois).—Distillery premises, . . .	240,000
15 June, 1904	New York.—S.S. "General Slocum," a large wooden passenger boat. 1,000 lives lost. . . .	
26 Aug., 1904	Antwerp (Hoboken).—Petroleum stores, . . .	250,000
Feb., 1905	New Orleans (La.).—Railroad terminal and warehouse property, ...	640,000
Feb., 1905	Boston (Mass.).—Wharves and steamers, . . .	250,000
Feb., 1905	Hot Springs (Ark.).—General conflagration, . .	300,000
20 Feb., 1905	Indianopolis (Ind.).—Several business blocks, . .	200,000
Mar., 1905	Cedar Rapids (La.).—Cereal mills and elevator, . .	300,000
Feb., 1906	E. St. Louis (Illinois).—Grain elevator, ...	200,000
Feb., 1906	Duluth (Minn.).—Grain Elevator, ...	200,000
Feb., 1906	Moncton (N.B.).—Railroad property, ...	200,000
Mar., 1906	Newport (R.I.).—Passenger steamer and other property	200,000
18 April, 1906	San Francisco.—The great fire after a shock of earthquake over an area of 7 square miles. 1,000 lives lost, ...	50,000,000
19 July, 1906	Dundee.—Bonded and other warehouses, ...	450,000
20 Oct., 1906	Selby (Yorks).—Abbey church burnt out. . . .	
April, 1907	New York (N.Y.).—Street railroad car barns, . .	298,000
Nov., 1907	Superior (Wis.).—Grain elevator, mills and other property, ...	453,600
Jan., 1908	New York City (N.Y.).—Business block, . . .	486,000
Jan., 1908	Chicago (Illinois).—Wall paper store, ...	224,000
Jan., 1908	Kenora (Ont.).—Flour mill and elevator, ...	200,000
April, 1908	Chelsea (Mass.).—Conflagration, ...	2,400,000
May, 1908	Atlanta (Ga.).—Conflagration, ...	300,000
June, 1908	Three Rivers (Quebec).—Conflagration, ...	400,000
July, 1908	Boston, East (Mass.).—Railroad wharves and elevator,	300,000
Aug., 1908	Fernie (B.C.).—Conflagration, ...	694,000
Aug., 1908	New Orleans (La.).—Conflagration, ...	280,000
Sept., 1908	Chisholm (Minn.).—Conflagration. Entire town, .	340,000
25 Oct., 1908	Bloemfontein (O.F.S.).—Government Buildings. Electrical wire in roof, ...	45,500
Feb., 1909	Christchurch (N.Z.).—Block of buildings, . . .	300,000
April, 1909	Chicago (Illinois).—Grain elevator, ...	200,000
Aug., 1909	Decatur (Illinois).—General Conflagration, . .	200,000
Oct., 1909	Quebec (Que.).—Grain elevator and docks, . .	240,000

Date.	Place.	Damage.
A.D.		
20 Dec., 1909	London.—Battersea drapery store. 8 employees killed.	
Jan., 1910	Kilburn.—Drapery shops, ...	£100,000
May, 1910	Ford City (Pa.).—Plate Glass works	300,000
May, 1910	Kansas City (Kan.).—Soap factory and adjoining property, ...	300,000
May, 1910	Minneapolis (Min.).—Implement warehouses, . .	200,000
July, 1910	Campbeltown (N.B.).—Conflagration, . . .	700,000
July, 1910	Marinette (Wis.).—Lumber, ...	240,000
July, 1910	Rat Portage (Man.).—Lumber, ...	200,000
July, 1910	Arnprior (Ont.).—Lumber, ...	200,000
Aug., 1910	Southern Oregon.—Timber fires (forests), . . .	220,000
Aug., 1910	Brussels.—Brussels Exhibition, ...	1,750,000
Oct., 1910	Minnesota, Montana and Idaho States.—Forest fires, .	2,800,000
Oct., 1910	Victoria, (B.C.).—Departmental stores and other property, ...	200,000
Jan., 1911	Little Rock (Ark.).—Business block, . . .	200,000
Feb., 1911	Jefferson City (Mexico).—State House building, .	200,000
Mar., 1911	Albany (New York).—State Capitol building, . .	1,100,000
Mar., 1911	Minneapolis (Minnesota).—Business block, . .	236,000
Mar., 1911	Chicago (Illinois).—Cold storage warehouse, . .	220,000
Mar., 1911	Benton (Philadelphia).—Whisky warehouse, . .	200,000
April, 1911	Bangor (Maine).—Conflagration, ...	740,000
May, 1911	Coney Island (New York).—Amusement buildings, .	445,000
July, 1911	Porcupine Dist. (Ontario).—Mining property and lumber (forest fires), ...	700,000
July, 1911	Waters (Michigan).—Lumber, ...	225,000
Dec., 1911	Owen Sound (Ontario).—Two elevators and railroad cars, ...	250,000
Jan., 1912	New York (U.S.).—Offices of the *Equitable Life* Assurance Society of U.S., ...	400,000
Jan., 1912	New York (U.S.).—Terminal warehouses, ...	220,000
Feb., 1912	Houston (Texas).—Cotton compresses and other buildings, ...	900,000
Feb., 1912	Philadelphia (Philadelphia).—Millinery factory and adjoining property, ...	220,000
Feb., 1912	Halifax (N.S.).—Sugar refinery, ...	200,000
June, 1912	Chicoutimi (Quebec).—Conflagration, ...	240,000
July, 1912	Vancouver (British Columbia).—Wholesale warehouses, etc., ...	350,000
Sept., 1912	Ocean Park (California).—Hotels, casino, and stores, .	225,000
Oct., 1912	Benicia (California).—Arsenal, ...	200,000
Oct., 1912	Philadelphia (Philadelphia).—Wharves and railroad property, ...	200,000
Nov., 1912	Kensington.—Drapery stores. 5 girls killed. . .	
Feb., 1913	Savannah (Geneva).—Wharves and railroad property, .	220,000
June, 1913	Long Island City (New York).—Paper box factory and adjoining property, ...	200,000
Sept., 1913	Hot Springs (Ark.).—Conflagration, ...	445,000
Feb., 1914	Clinton (Texas).—Cotton, ...	200,000
Mar., 1914	Portland (Oregon).—Dock warehouse and steamers, .	200,000
May, 1914	Cleveland (Ohio).—Lumber yards, ...	250,000
Sept., 1914	Tacoma (Washington).—Meat packers, ...	200,000
Nov., 1914	Galveston (Texas).—Grain elevator (sprinklered), .	200,000
Nov., 1914	Jeannette (Philadelphia).—Glass warehouse, . .	200,000
Dec., 1914	West Orange (New York).—Edisons' works, . .	500,000
Sept., 1915	Newport News (Va.).—Grain elevator and adjoining, .	400,000
Nov., 1915	Bethlehem (Pa.).—Ordnance plant, ...	300,000
Nov., 1915	Pine Bluff (Ark.).—Cotton compress, ...	250,000
Feb., 1916	Fall River (Mass.).—Department store, . . .	400,000
Feb., 1916	Ottawa (Ont.).—Parliament buildings, . . .	400,000
Feb., 1916	Brooklyn (N.Y.).—Piers and steamers, . . .	400,000
Mar., 1916	Paris (Texas).—Conflagration, ...	2,200,000
Mar., 1916	Augusta (Ga.).—Conflagration, ...	850,000
July, 1916	Jersey City (N.J.).—Warehouses and steamers, . .	4,000,000
Jan., 1917	Kingsland (N.J.).—Munition factory, . . .	2,400,000

Date.	Place.	Damage.
A.D.		
Jan., 1917	Haskell (N.J.).—Powder factory, ...	£300,000
Feb., 1917	Pittsburg (Pa.).—Munition plant, ...	800,000
May, 1917	Atlanta (Ga.).—Conflagration (dwelling-house section),	1,000,000
Aug., 1917	Rigaud (Que.).—Munition works, ...	400,000
Aug., 1917	Drumright (Okla.).—Oil tanks, ...	400,000
Oct., 1917	Brooklyn (N.Y.).—Grain warehouses, ...	400,000
Oct., 1917	Baltimore (Md.).—Railroad piers and merchandise, .	700,000
Mar., 1918	Jersey City (N.J.).—Warehouses, ...	300,000
April, 1918	Kansas City (Mo.).—Business blocks, . . .	600,000
May, 1918	St. Louis (Mo.).—Packing plant (meat), . . .	450,000
June, 1918	St. Louis (Mo.).—Government warehouse, . .	600,000
June, 1918	Noxen (Pa.).—Tannery, ...	450,000
July, 1918	New York (N.Y.).—Steamers and oil cargo, . .	600,000
Aug., 1918	Owensboro (Ky.).—Whisky distillery, . . .	800,000
5 Sept., 1918	Colchester.—Theatre Royal destroyed. . . .	
5 Sept., 1918	Glasgow.—Grand Theatre, ...	50,000
Oct., 1918	Minnesota (Minn.).—Forest fires (Colquet and 25 other towns involved), ...	5,000,000
Oct., 1918	Morgans Point Station (J N).—Munition plant, .	4,000,000
Oct., 1918	Trenton (Ont.).—Chemical works, ...	360,000
Jan., 1919	River plant (R I).—Textile mill, ...	250,000
Feb., 1919	Savannah (Ga.).—Fertiliser factory, cotton and railroad terminals, ...	800,000
Feb., 1919	Stamford (Conn.).—Dye extract factory, . . .	250,000
April, 1919	Yokohama.—Dwelling-houses, etc., ...	5,000,000
May, 1919	Cedar Rapids (Ia.).—Starch works, ...	600,000
June, 1919	Norfolk (Va.).—Tobacco warehouse, . . .	650,000
Aug., 1919	Detroit (Mich.).—Lumber mill and hotel, . . .	320,000
Aug., 1919	Port Colborne (Ont.).—Government Elevator, . .	360,000
Aug., 1919	Rock Island (Ill.).—Tractor Factory, . . .	300,000
Sept., 1919	Long Island City (N.Y.).—Oil works and buildings adjoining, ...	800,000
Sept., 1919	Sheffield (Ala.).—Nitrate warehouse and plant, . .	400,000
Sept., 1919	Big Horn (Wyo.).—Forest fires, ...	260,000
Sept., 1919	Omaha (Meb.).—Court House, ...	220,000
Jan., 1920	Sheboygan (Wis.).—Tannery, ...	430,000
Jan., 1920	Lancashire.—Dye works, ...	300,000
Feb., 1920	New York (N.Y.).—Ship, yacht and yard, . .	200,000
Mar., 1920	Dayton (Ohio).—Tobacco warehouse, . . .	220,000
April, 1920	Brooklyn (N.Y.).—Iron works, steamer and lighters, .	300,000
April, 1920	Dallas (Tex.).—Aviation repair depot, . . .	200,000
April, 1920	Little Rock (Ark.).—Railroad station, . . .	200,000
May, 1920	San Francisco (Cal.).—Glass works, ...	200,000
May, 1920	Oldham.—Shipyard, ...	250,000
June, 1920	Chicago (Ill.).—Freight warehouse and cars, . .	300,000
June, 1920	Galveston (Tex.).—Sisal warehouse and wharf, . .	300,000
July, 1920	New Orleans (La.).—Sisal warehouse, . . .	240,000
July, 1920	Manistee (Mich.).—Lumber and salt plant, . .	200,000
July, 1920	Kansas City (Mo.).—Motion picture exchange, . .	200,000
Aug., 1920	Bradford (O.).—Mercantile blocks, ...	200,000
Aug., 1920	Darwen.—Wall-paper works, ...	260,000
Sept., 1920	Dewsbury.—Rag warehouse, ...	200,000
Sept., 1920	Perth Amboy (N.J.).—Asphalt works, . . .	500,000
Sept., 1920	Sacramento (Cal.).—Packing warehouse, . . .	300,000
Oct., 1920	Kingsville (Tex.).—Round-house and machine shop, .	200,000
Oct., 1920	St. Louis (Mo.).—Car plant and lumber, . . .	200,000
Oct., 1920	Cameron (Tex.).—Cotton Compress	200,000
Oct., 1920	Washington (D.C.).—Naval Air station, . . .	200,000
Nov., 1920	New Orleans (La.).—Wharf, ...	500,000
Nov., 1920	Warsaw (N.C.).—Lumber plant, ...	200,000
Nov., 1920	Brownsville (Pa.).—Coal mines, ...	200,000
Nov., 1920	Liverpool.—Damage by Sinn Feiners, . . .	1,000,000
Oct., 1920	London.—Hop Exchange and wine stores, . .	650,000
Jan., 1921	Washington (D.C.).—Census Records building, . .	400,000
Jan., 1921	Charleston W. (Va.).—State Capital building, . .	250,000

Date.	Place.	Damage.
A.D.		
Jan., 1921	Athens (Ga.).—Conflagration, ...	£300,000
Jan., 1921	Worcester (Mass.).—Conflagration, ...	300,000
Jan., 1921	New Haven (Conn.).—Dry goods stores, . . .	200,000
Feb., 1921	Augusta (Ga.).—Hotel building, ...	200,000
Feb., 1921	Buffalo (N.Y.).—Airplane plant, ...	200,000
Mar., 1921	Chicago (Ill.).—Grain elevator, ...	500,000
Mar., 1921	Fresno (Cal.).—Office building, ...	200,000
April, 1921	Santa Barbara (Cal.).—Hotel stores, . . .	300,000
May, 1921	Toronto (Ont.).—Military storehouse, . . .	500,000
May, 1921	London.—Tottenham. Boot factory, . . .	300,000
May, 1921	Perth.—Blair Drummond Mansion, ...	200,000
4 June, 1921	London.—Edmonton Cinema panic. 20 children slightly injured.	
11 June, 1921	Edinburgh.—Garrick Theatre destroyed. . . .	
June, 1921	McKeesport (Pa.).—Cedar and tinplate works, . .	400,000
June, 1921	Jacksonville (Fla.).—Road materials warehouse, .	350,000
June, 1921	Pittsburg (Pa.).—Business section, ...	200,000
July, 1921	Whiting (Ind.).—Oil plant, ...	400,000
July, 1921	Lucas (Tex.).—Oil tanks, ...	300,000
July, 1921	Elmira (Cal.).—Dwellings and grain, . . .	200,000
July, 1921	Clearing (Ill.).—Sisal warehouse, ...	200,000
July, 1921	Lindin (N.J.).—Asphalt plant, ...	450,000
Aug., 1921	Hoboken (N.J.).—Piers, ...	700,000
Aug., 1921	Chicago (Ill.).—Warehouses, ...	200,000
Aug., 1921	Philadelphia (Pa.).—Oil refining plant, . . .	200,000
Aug., 1921	London.—Hackney Wick. Timber yard, . . .	500,000
Sept., 1921	Milwaukee (Wis.).—Tannery, ...	300,000
Sept., 1921	Jeffries, (Wis.).—Business district, ...	200,000
Oct., 1921	Morrilton (Ark.).—Cotton compresses, . . .	260,000
Oct., 1921	Charlestown (S.C.).—Warehouses, ...	260,000
Oct., 1921	Leeds.—Soap work, ...	230,000
Nov., 1921	Forfarshire.—Kinnaird Castle, ...	200,000
Nov., 1921	Los Alamitos (Cal.).—Sugar warehouse, . . .	300,000
Nov., 1921	Augusta (Ga.).—Business section, ...	200,000
Nov., 1921	Weehawken (N.J.).—Railroad piers and flour warehouse, ...	400,000
Dec., 1921	Kirribilli (Australia).—About 32,000 bales of wool burnt, ...	750,000
Jan., 1922	West Hartlepool.—Docks. Timber storage ground, .	600,000
Jan., 1922	Glasgow.—N.B. Railway Goods Station, . . .	250,000
Jan., 1922	Allonez (U.S.).—Ore docks, ...	400,000
Mar., 1922	Peterborough.—Engineering works, ...	200,000
Mar., 1922	Chicago (U.S.).—Block of office premises and other buildings, ...	1,600,000
Mar., 1922	Quebec.—The Basilica of St. Anne de Beaupré, . .	240,000
April, 1922	London.—Victoria Docks. 4,400 hogsheads, 12,000 bales, and 4,000 cases of tobacco, ...	1,000,000
May, 1922	Rothes (Scotland).—Distillery, ...	200,000
May, 1922	Perth Amboy (New Jersey).—Lead plant, . .	260,000
June, 1922	Arverne (Long Island).—Conflagration, . . .	400,000
July, 1922	Baltimore.—Grain elevators and railroad property, .	1,000,000
July, 1922	McGill (Nevada).—Copper concentrating plant, . .	400,000
July, 1922	Beaumont (Texas).—Oil tanks, ...	400,000
July, 1922	New York.—City warehouses, ...	300,000
July, 1922	Haidar Pasha.—250 houses and business premises, .	200,000
Aug., 1922	Salonica.—Tobacco warehouses, ...	250,000
Sept., 1922	Smyrna.—Terrific conflagration. Almost whole town destroyed.	
Sept., 1922	Terre Haute (Indiana).—Hominy plant, . . .	1,600,000
Sept., 1922	New Orleans.—Wharves, warehouses and railway freight cars, ...	1,000,000
Sept., 1922	Napoleonville (Louisiana).—Sugar refinery, . .	400,000
Sept., 1922	Sugar Pine (California).—Lumber, ...	400,000
Oct., 1922	Ontario.—Forest fires, ...	3,000,000
Oct., 1922	Paris.—" Printemps " drapery establishment, . .	750,000

Date.	Place.	Damage.
A.D.		
Dec., 1922	Astoria (Oregon).—Destroyed greater part of business quarters, ...	£3,000,000
Dec., 1922	Newbern (N. Carolina).—Conflagration, . . .	500,000
Dec., 1922	Geneva.—Northern railway station practically destroyed, ...	400,000
Feb., 1923	Omaha.—Warehouses at the packing plant of the Armour Meat Company, ...	400,000
April, 1923	Rancoca (New Jersey).—Stud farm stables with valuable horses lost, ...	750,000
April, 1923	New Brunswick.—Forest fires covering an area of roughly 250 square miles, ...	4,000,000
14 April, 1923	London.—Victoria Dock—Tobacco destroyed, . .	1,000,000
Sept., 1923	Berkeley (California).—Forest fire and 600 buildings, .	2,500,000
Sept., 1923	Japan.—As result of earthquake about $\frac{7}{10}$ of Tokyo and the whole of Yokohama and of Yokosuka, destroyed, ...	200,000,000
Sept., 1923	Smyrna.—Conflagration attributed to the war between the Turkish and Greek armies, ...	20,000,000
April, 1924	London.—Butler's Wharf, ...	350,000
April, 1924	Belfast.—Soft goods warehouse, ...	250,000
June, 1924	Mukden (Manchuria).—Textile mill, ...	500,000
Aug., 1924	Tallulah (Labrador).—Lumber, ...	600,000
Oct., 1924	Canton.—Conflagration result of insurrection, . .	4,000,000
Feb., 1925	Kansas City.—Automobile exhibition and adjoining property, ...	800,000
Mar., 1925	Tokio.—Conflagration, area of 2¼ miles destroyed, .	Unknown.
18 Mar., 1925	London.—Madame Tussaud's "Waxworks," . .	250,000
Apr., 1925	Newark, New Jersey.—Factory, ...	800,000

APPENDIX A.

Table I.—Densities of Gases and Vapours.

(Air taken as Unity.)

Lighter.		Heavier.	
Hydrogen,	0·069	Oxygen,	1·105
Coal Gas,	0·40-0·60	Phosphuretted Hydrogen,	1·185
Ammonia,	0·588	Sulphuretted Hydrogen,	1·192
Acetylene,	0·898	Air Gas	1·260-1·317
Water (Steam),	0·622	Carbon Dioxide	1·519
Carbon Monoxide,	0·967	Alcohol,	1·613
Nitrogen,	0·970	Chlorine,	2·448
Mond Gas,	0·987-1·015	Ether,	2·565
Water Gas,	0·51	Carbon Disulphide,	2·645
Generator Gas,	0·830-1·00	Benzol,	2·770
		Chloroform,	4·215
		Amyl Acetate,	4·600

Table II.—Explosive Ranges of Gases when Mixed with Air.

	Per Cent.		Per Cent.
Acetylene,	3·2-52·2	Ether Vapour,	2·9- 7·5
Alcohol Vapour,	4·0-13·6	Ethylene,	4·2-14·5
Benzine Vapour,	2·5- 4·8	Hydrogen,	9·5-66·5
Benzol Vapour,	2·7- 6·3	Methane,	6·2-12·7
Carbon Monoxide,	16·6-74·8	Pentane,	2·5- 4·8
Coal Gas,	8·0-19·0	Water Gas,	12·5-66·6

Table III.—Approximate Fusing Points.

	Degrees.			Degrees.	
	F.	C.		F.	C.
Aluminium,	1,220	660	Lead,	625	330
Bismuth,	500	260	Nickel,	2,730	1,500
Brass,	1,650	900	Platinum,	3,200	1,760
Copper,	1,980	1,080	Sulphur,	239	115
Glass, (see note p. 519)	845-1,650	450- 900	Silver,	1,760	960
Gold,	1,940	1,060	Steel, (see note p. 519)	2,370-3,280	1,300-1,800
Iron, (cast).	1,925-2,370	1,050-1,300	Tin,	450	233
Iron, (wrought).	2,900-4,000	1,600-2,200	Zinc,	770	412

Glass.—The effect of heat on glass differs from its effect on metal. In the case of glass, there is no definite point of fusion; but gradual softening will take place, such softening being dependent in its extent upon the temperature, and the period of its exposure thereto.

The temperature necessary to bring about softening or "creeping" varies with the composition of the glass, but the following examples will indicate to a fireman how, from a survey of glass of various descriptions, an approximate estimate of the temperature reached during a fire may be arrived at.

Window Glass, Plate Glass, and Mirror Glass.—Incipient softening may take place as low as 1,025-1,070° F. (550-575° C.). Warping and buckling between 1,115-1,385° F. (600-750° C.), dependent upon the time of exposure and the character of the support. Rapid softening between 1,385-1,650° F. (750-900° C.).

Glass in which wire is embedded during manufacture receives great support, and the wire causes a delay in the sagging and buckling, but the surface flow would be as evident as in the ordinary unwired glass.

Cut Glass and Decanters, if made from a lead-potash glass would show incipient softening at about 845-890° F. (450-474° C.). Deformation of the vessels would take place between 935-1,200° F. (500-650° C.), the extent being dependent upon the time the glass is exposed to the heat. Soda-potash-lime glass would probably stand 212° F. (100° C.) higher.

Moulded or Pressed Glass may be expected to become deformed at about 1,200-1,385° F. (600-750° C.).

Wine Bottles are very varied in their composition, but a temperature of 1,300-1,385° F. (700-750° C.) for one hour would produce sagging and bending of the necks.

Steel is intermediate between cast- and wrought-iron in regard to the amount of carbon which it contains. The remarkable thing about steel is that when it is heated and then suddenly cooled by plunging into cold water it becomes exceedingly hard, so much so that it has the power of scratching glass. Curiously enough, if this hard steel is again heated and then allowed to cool *slowly*, it is found to be nearly as soft as ordinary iron. By regulating the temperature to which the hardened steel is exposed the second time, any required degree of hardness may be attained. Articles made of steel, such as razors, scissors, and watch-springs, are therefore first hardened, and then "tempered" by heating them to a point between 430° and 550° F. (221° and 260° C.), the temperature varying according to the purpose for which the article is to be used. A razor, for example, is heated only to 430° F. (221° C.), a temperature at which the metal acquires superficially a pale yellow colour, due to the formation of a film of oxide. Watch-springs or sword-blades, on the other hand, which should be softer and more elastic, are tempered by heating to 550° F. (260° C.), and the colour of the surface film passes through various shades—yellow, brown, purple, and blue—as the temperature rises. The degree of heat attained in tempering may in fact be judged from the colour of the surface. Thus hardened steel which has been heated to 430° F. (221° C.), and then allowed to cool slowly, is said to be "tempered to the yellow," and is hard enough to take a fine cutting edge. It must be remembered that steel which has been hardened without being tempered is of no use for ordinary purposes; it is too brittle.

Aluminium is one of the most common constituents of the earth's crust, occurring in the combined state as mica, felspar, clay, and slate, exceedingly light, is not easily tarnished and has considerable resistance to the action of animal and vegetable juices.

Aluminium in the mass is not easily oxidised in air, probably because it gets coated with a thin film of oxide which acts as a protective layer, the powdered metal burns vigorously, like magnesium, when it is heated, and when mixed with ferric oxide it is called thermit.

Thermit consists of :—Oxide of Iron, 75 per cent.
Aluminium, 25 per cent.

A flux consisting of $\frac{2}{3}$ Peroxide of barium or other carrier of oxygen and $\frac{1}{3}$ Aluminium is used for igniting the thermit, but in order to prevent the whole mass becoming heated and burning in an explosive manner, the flux is used in the form of pellets. The pellet of flux can be conveniently lighted by means of a magnesium wire, which burns on applying a match.

The interior of a mass of glowing thermit will reach a temperature of from 4,532° to 5,432° F. (2,500° to 3,000° C.).

Thermit is much used for fusing and joining tramway rails, and was the active ingredient used in the early pattern of incendiary bombs dropped from the German aeroplanes.

Hydrogen and Oxygen.—A few figures will show how the amounts of hydrogen and oxygen diminish regularly as we pass from wood to a hard coal like anthracite. To make the figures comparable, the amount of carbon is put as equal to 100 in each case.

The amount of hydrogen and oxygen found in :—

	Carbon.	Hydrogen.	Oxygen.
Wood,	100	12	88
Peat,	100	9	56
Lignite,	100	8	42
Bituminous Coal,	100	6	21
Anthracite,	100	3	2

TABLE IV.—ANNEALING TEMPERATURES OF METALS.

	Degrees. F.	Degrees. C.
Pale Yellow,	428	220
Straw Yellow,	445	230
Brown,	500	260
Purple,	530	277
Pale Blue,	550	288
Dark Blue,	560	293
Blue-Black,	600	316
Electric arc in the carbide furnace,	6,330	3,500
The Goldschmidt thermit process with aluminium powder,	5,070	2,800
Blowpipe and soldering lamp temperatures,	1,835-3,600	1,000-2,000
Temperature of laboratory electric furnace,	2,190-2,730	1,200-1,500
Bunsen Burner flame,	2,400	1,350

TABLE V.—Colours Corresponding to Temperature.

	Degrees. F.	Degrees. C.		Degrees. F.	Degrees. C.
Lowest red heat visible in the dark,	635	325	Orange, . .	2,010	1,100
Dull red, . .	1,290	700	Bright Orange, .	2,190	1,200
Brilliant red, . .	1,470	800	White heat, . .	2,370	1,300
Cherry red, . .	1,650	900	Bright white heat, .	2,550	1,400
Bright red, . .	1,830	1,000	Dazzling white heat,	2,730	1,500

TABLE VI.—Boiling Points.

	F.	C.		F.	C.
Petroleum Ether,	97-158	36-70	Coal Tar Benzol	176	80
Acetone, . .	132	55	Sulphuric Acid (Chamber), .	266-640	130-338
Carbon Tetra-chloride, . .	170	77	Oil of Turpen-tine, . .	305-320	152-160
Alcohol, . .	172	78	Camphor Oil,	407-572	204-300

TABLE VII.—Flash Points.

	F.	C.		F.	C.
Carbon Disulphide, .	−4	−20	Acetone, . .	35	2
Ether, ...	−4	−20	Colloidin, . .	40	5
Petroleum Ether, .	−4	−20	Amyl Acetate, .	65	18
Coal Tar Benzol, .	−4	−15	Brandy, Whisky, and Gin, .	82-90	28-32

Temperature required to Ignite Different Substances.

(*Kemp*. 1925.)

	° F.	° C.
Phosphorus, transparent,	112	44·4
Bisulphide of cargon,	300	143·3
Fulminating powder,	370	187·8
Fulminate of mercury,	390	198·9
Gun-cotton,	430	221·1
Nitro-glycerine,	490	254·4
Phosphorus, amorphous,	500	260·0
Rifle-powder,	550	287·8
Forced gunpowder,	560	293·3
Picrate powder for torpedoes,	570	299·0
Charcoal from willow wood,	660	349·0
Picrate powder for cannon,	720	382·2
Very dry pine wood,	800	426·7
Dry oak wood,	900	480·2

MISCELLANEOUS TEMPERATURES (*Kemp*, 1925).

	° F.	° C.
In the Bessemer furnace,	4,000	2,204
Puddling furnace,	3,500	1,927
Cupola,	3,000	1,649
Heat of common fire,	1,100	593·3
Red-heat in daylight,	1,070	571·1
Iron red in dark,	752	400·0
Mean temp. of earth,	50	10·0
,, ,, torrid zone,	75	23·8
,, ,, temp. zone,	50	10·0
,, ,, Polar region,	20	6·6
Highest temp. of wind,	117	47·2
Temp. of human blood,	98	36·6
A comfortable room,	70	21·1
Mean temperature of ocean,	62	16·6
1 alcohol, 1 water freezes,	−7	−21·6
Mean temp. of poles,	−13	−25·0
Interstellar space,	Abs.	0
Greatest natural cold,	−56	−48·5
Vinous fermentation,	65	18·3
Acetous fermentation begins,	78	25·5
Acetification ends,	88	31·1
Phosphorus takes fire,	112	44·4
Greatest artificial cold produced (Kamerlingh Ommes),	−457·9	−272·18

BEAUFORT WIND SCALE.

Beaufort number.	Description of wind.	Mean Wind force in lbs. per sq. ft. at standard density.	Equivalent velocity miles per hour.	Beaufort number.
0	0	0	0	0
1	Light breeze.	0·01	2	1
2		0·08	5	2
3		0·28	10	3
4	Moderate breeze.	0·67	15	4
5		1·31	21	5
6	String wind.	2·3	27	6
7		3·6	35	7
8	Gale forces.	5·4	42	8
9		7·7	50	9
10	Storm forces.	10·5	59	10
11		14·0	68	11
12	Hurricane.	above 17·0	above 75	12

The Morse Code.—Most signalling codes are based on this alphabet or "dot-dash."

A . —	H	O — — —	V . . . —
B — . . .	I . .	P . — — .	W . — —
C — . — .	J . — — —	Q — — . —	X — . . —
D — . .	K — . —	R . — .	Y — . — —
E .	L . — . .	S . . .	Z — — . .
F . . — .	M — —	T —	
G — — .	N — .	U . . —	

Fire Cups (Fig. 271).—Cresset stones or fire cups were contrivances for providing perpetual fire in churches in order that candles might be ignited from them for the services in former times, and the villagers might obtain their fire without recourse to tinder and flint. Very few of these ancient relics survive, but there is still a rare example near the church door at Lewannick, in Cornwall. It is a round block of stone with flat surface, 22 inches across at the top, standing on an eight-sided pedestal and having

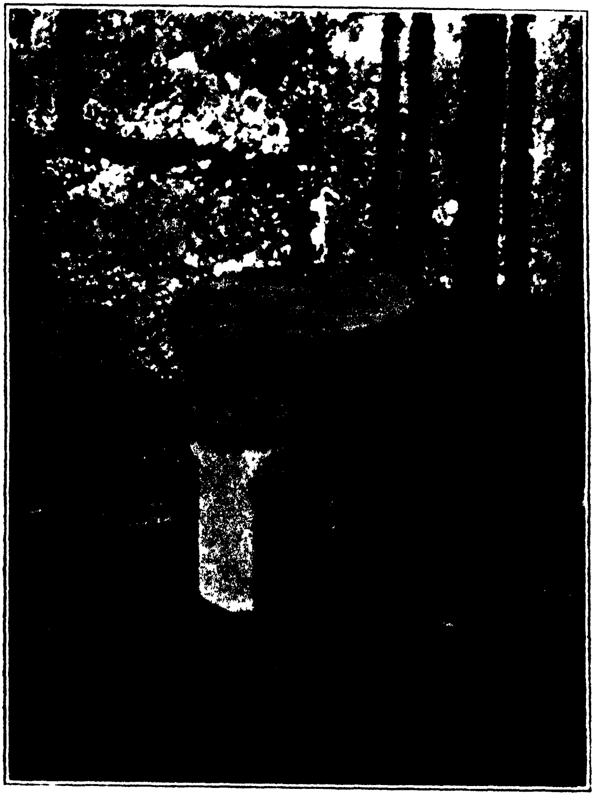


Fig. 271.

7 cup-like cavities. These were originally filled with oil, and wicks were placed in them and ignited. At Wool Church, Dorset, is an example with only 5 cups, made of the Purbeck marble quarried locally. This number of cavities was discovered at Furness Abbey ruins; at Calder Abbey 16 cups were found, and at York 6. These internal fire cups must not be confused with the iron "cressets," or fire buckets, seen occasionally upon the corner turrets of church towers, as at Hadley, near Barnet. Such were used as beacons to guide belated travellers along unfamiliar roads by night.

SPECIMEN FORM OF NOTICE TO FIX HYDRANT PLATES.

BOROUGH OF...
OR URBAN DISTRICT COUNCIL OF..........................
OR RURAL DISTRICT COUNCIL OF...........................

FIRE BRIGADE.

PUBLIC OFFICES,
..........................19

To...
The Owners and Occupiers of the house (or building) situate and being No..................
....

SIR,

I am instructed by the ....Council to inform you that, in pursuance of the power contained in Section 124 of the Towns Improvements Act, 1847, and Section 66 of the Public Health Act, 1875, the Council is about to put upon some conspicuous place on the above-mentioned house (or building) an enamelled iron tablet, about six inches square, to indicate the position of a fire hydrant in..
....

Dated this........................day of........................19

....
Clerk of the Council,
or other duly authorised officer.

To Test a Manual Engine for Suction.—Remove the suction and delivery-caps, and put the handles down at one side, say the left or near side. Screw on to the suction inlet a piece of pipe with a vacuum-gauge and an air-cock.

Close the air-cock, and raise the near side handle to the highest point, and stop it there.

Should the gauge show a vacuum of about 15 inches, or 7½ lbs. on the square inch, and hold it, it will be a sign that the left-hand side of the pump is in working order.

Should the pressure go back quickly, it will show that there is a leak, and all joints must be examined, and stopped. Before repeating this test, it is necessary to open the air-cock full, so as to allow the air to enter.

Test the right-hand pump in the same way.

Any person of experience can apply this test, by placing his hand over the inlet, with results sufficiently accurate for almost all practical purposes.

INSTRUCTIONS FOR THE CARE AND MANAGEMENT OF LEATHER HOSE.

Receipt for Dubbing.—Melt 2¼ lbs. of perfectly clean tallow, free from salt, and mix with it, when hot, 1 gallon or 9 lbs. of cod oil.

The best mode of clearing tallow for this purpose is to boil it in water, which will take up the salt and other impurities, and can be poured away when cold.

Care must be taken not to boil the oil, as this would deprive it of some of its principal qualities.

The tallow must be first melted, and when it is warm the oil to be poured on and stirred into it until the whole mixture is perfectly cold. This will make a good stiff dubbing.

To apply the Dubbing.—Thoroughly wet the hose with clean fresh water, and brush it well so as to leave no dirt on it; then hang it up to dry, either by the centre, or, if there is room enough, by one end, but not on any account by both ends, as in this latter way it would not drain itself properly.

When it is about half-dry, which it should be in a day or a day and a half after it has been hung up, rub it well on the outside with the dubbing, and hang it up again in a dry airy place, but not in the sun, or near a fire, and, as the remaining water evaporates, the dressing will enter the leather and make it soft and pliable.

To keep the Couplings in Order.—The coupling screws should always be kept perfectly clean, and free from grit or dirt, and in cleaning them great care must be taken not to damage the threads.

The outside of the swivel ring, containing the female screw, and the lugs of both screws, should be highly polished with brick-dust or rotten stone; but the threads and waterways should be merely rubbed bright with a brush dipped in oil, and wiped off afterwards with cotton waste, or some other soft substance.

This, if done properly, will remove all dirt from the screws without injuring the thread, as brick-dust or any other gritty substance would do.

Should there be any reason to suppose that a screw is damaged, however slightly, in any way that may cause delay or difficulty in making the joints, the length of hose to which it belongs must be laid aside, and on no account brought out to a fire again until the couplings have been carefully tested with the steel gauge, and, if necessary, adjusted to the proper standard.

Particular care must be taken to see that the leather washers are clean, and free from grit, and when this has been ascertained, they should be well rubbed with pure oil, so as to keep them soft and in good order, and the swivel ring should be so slack that the female screw should revolve freely.

If these rules are strictly observed, the difficulty of making perfectly tight joints when laying out the hose will be much reduced.

To make up the Hose for Use.—After the first coat of dressing has been absorbed, give the whole of the leather a light brush over with a small additional quantity of dubbing, and then roll up the hose in coils, commencing at the male screw, and taking particular care to have all the rivets in the centre of the outside, so that, when the coils are afterwards unrolled for use, the hose will come off in straight lines without kinks or twists.

On the attention which is paid to this point depends almost entirely

the success of the firemen in the proper laying out of long lines of hose with the quickness and accuracy necessary for fire service.

In making up the hose, the hand loops or beckets should be folded up and turned in so as not to protrude from the coil.

The collar of the leather strap should be slipped up to within 6 or 8 inches of the female screw, and so turned that the rivet and strap should be on the outside, and care must be taken to avoid allowing the collar to come too near the end; as in such a case the heaving up of the strap in the buckle might damage the shank of the screw.

To Preserve the Hose.—The coils must be occasionally examined, and, if the slightest appearance of mould or damp be found on them, they should be opened, carefully brushed over with a dry brush, and hung up for a short time, after which they may, if very dry, be again brushed over with a light coat of dubbing, previously to being rolled up for use as before.

The strength of the leather is in the fibre, and if this be allowed to become hard it cracks, and the hose consequently bursts when put under pressure.

Constant attention must, therefore, be paid to keep the hose soft and pliable, and to prevent it becoming dry and hard, which it is certain to do, either if it does not receive a good coat of dressing at the proper time as before explained, or if it is left too long without dressing.

Leather hose should, if possible, be kept in a warm dry place with free ventilation, and, where this cannot be done, as in the hose-box of a fire engine, it is advisable to keep the hose-box lid occasionally open, so as to admit a sufficient quantity of fresh air to prevent the dressing becoming rancid.

"And now remain these three things,

Fire Insurance,
Fire Protection,
Fire Prevention,

Fire Insurance saves nothing—
it merely distributes the loss.

Fire Protection saves something—
at a high cost of upkeep.

Fire Prevention saves all—
at little or no cost."

Neill's Insurance News.

INDEX.

C

G

H

I

Q

R

S

T

U

V

W

X

Y

Z

DATE OF ISSUE

This book must be returned within 3/7/14 days of its issue. A fine of ONE ANNA per day will be charged if the book is overdue.